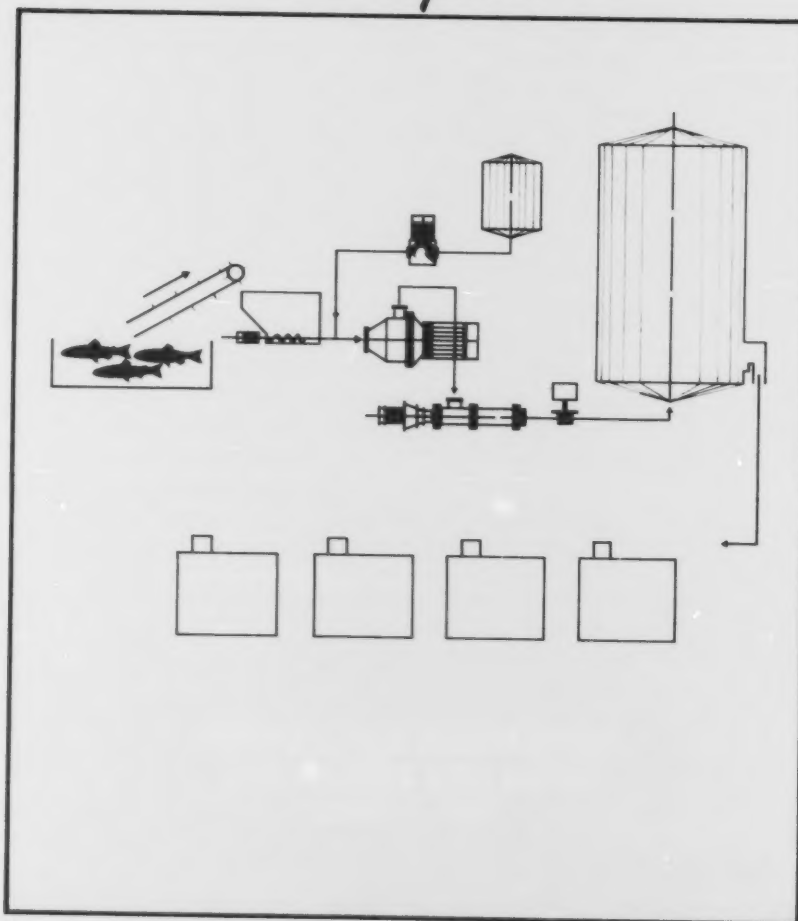


ATLANTIC FISHERIES

Development



 Canada



Fisheries
and Oceans

Pêches
et Océans

88-02615/

FISH SILAGE WORKSHOP

**Université Sainte-Anne
Church Point, Nova Scotia
June 16 - 17, 1987**

Sponsored by

**Department of Fisheries and Oceans
Fisheries Development Program
Scotia-Fundy Region
Halifax, N.S.**

Proceedings

General Education Series #7

également disponible en français

Notice

The views expressed in this publication are strictly those of the authors and not necessarily those of the Department of Fisheries and Oceans or the Government of Canada. The use of proprietary names does not imply endorsement of the product or company.

© Minister of Supply and Services
Cat. No. Fs-68-2/1-7E
ISSN 0835-7005

TABLE OF CONTENTS

Chairman's Introductory Remarks.....	7
Jean-Eudes Haché	
Fish Silage:	
A Review and some Recent Developments.....	8
Peter M. Jangaard	
Silage Processing Plants.....	34
Nils I. Viken	
Processing and Application of Concentrated Silage as Feed for Fish, Mink, Fox and Poultry.....	44
Ole P. Ulvestad	
Fish Silage as Feed for Salmon and Trout.....	56
Dr.Santosh Lall	
Fish Silage as Animal Feed.....	64
Ted VanLunen	
Overview of Fish Waste Utilization Programs.....	70
George Richard	
Fish Silage Report.....	72
Mike Drebot	
Fish Silage Evaluation for Salmonid Diets.....	80
Dr. R.H. Cook and Dr. C. Frantsi	
Silage Trial.....	82
John L'Aventure	
A project with Fish Silage as Hog Feed on Prince Edward Island.....	84
Dominic Johnson	
The Potential for Fish Silage.....	85
Andrée Gendron	
Other Activities: Newfoundland.....	90
Winston King	
Other Activities: TUNS.....	92
John H. Merritt	
I.M.A. Aquatic Farming.....	93
Brian Ives	
Agenda.....	95
Attendees.....	97

Workshop Organization

Chairman

Jean-Eudes Haché
Director-General, Scotia-Fundy Region
Department of Fisheries and Oceans
Halifax, N.S.

Organizing Committee

Peter M. Jangaard
Frank King
David Lemon

Fisheries Development Branch
Scotia-Fundy Region
Department of Fisheries and Oceans
Halifax, N.S.

Facilities and Coordination

Nadine Boudreau
Université Sainte-Anne
Church Point, N.S.

Proceedings: Translation, Editing and Layout

Germaine Comeau

ABSTRACT

Anon. (1987) Proceedings, Fish Silage Workshop, Church Point, Nova Scotia, June 16-17, 1987. Dept. of Fish. Oceans Canada, Gen. Ed. Ser. No. 7 : 103 p.

This publication contains the proceedings of the Fish Silage Workshop held at Church Point, Nova Scotia, June 16-17, 1987. The workshop was sponsored by the Canadian Department of Fisheries and Oceans under the Fisheries Development Program and attracted about 130 participants.

The proceedings contain fourteen papers presented or distributed at the workshop. Included is a review of recent developments in the production and use of fish silage concentrate especially in Norway and two papers by manufacturers of silage processing equipment. Several papers describe feeding trials with trout and salmon, and several domestic animals. Other papers give details of recent activities in Canada's Atlantic provinces, including various pilot plant studies and trials with the use of fish silage for fertilizer.

The workshop was designed as an information workshop and no recommendations for future development were formulated.

RÉSUMÉ

Anon. (1987) Rapport, Atelier sur l'ensilage du poisson, Pointe-de-l'Église, Nouvelle-Écosse, 16-17 juin, 1987. Min. Pêches Océans Canada, sér. Éd. gén. n° 7: 103 p.

Cette publication comprend les Actes de l'Atelier sur l'ensilage du poisson qui s'est tenu à Pointe-de-l'Église, Nouvelle-Écosse, les 16 et 17 juin 1987. Parrainé par le Programme de développement des pêches, Ministère des Pêches et Océans, l'atelier réunissait environ 130 participants.

Le rapport comprend quatorze présentations faites oralement ou distribuées aux participants pendant l'atelier. Les textes de ce rapport donnent un aperçu général de l'évolution récente de la production du poisson ensilé et du concentré de poisson ensilé, notamment en Norvège. Deux des orateurs étaient fabricants d'équipement pour la production de l'ensilage. Plusieurs textes présentés dans ce rapport font état d'essais sur l'alimentation de truites, de saumons et d'animaux domestiques. D'autres décrivent des activités récentes dans la région Atlantique du Canada, y compris certaines études qui ont été faites sur des usines-pilotes ainsi que des essais sur l'utilisation de l'ensilage comme engrais.

L'objectif de l'atelier était d'échanger des renseignements et aucunes recommandations sur le développement de l'ensilage ont été formulées.

CHAIRMAN'S INTRODUCTORY REMARKS

Jean-Eudes Haché,
Regional Director-General
Scotia-Fundy Region
Department of Fisheries and Oceans
Halifax, Nova Scotia
B3J 2S7

We are pleased to have this opportunity to host this workshop on the use of silage. I see by the turnout that it is a topic that is generating a great deal of interest, not only within our own department but also within the industry and the public at large. Certainly for us, it will be an excellent opportunity to encourage or sponsor the sharing of all the information that presently exists on that topic and also learn from those with much more experience than we have on this issue.

There will be a number of presentations made during the day by various people from our own Department, from provinces, from industry and we also have two guests from Norway who will share with us their knowledge and experience.

I do wish to take this opportunity to express our appreciation, on behalf of the Department of Fisheries and Oceans, to Université Sainte-Anne for their excellent cooperation. I especially want to thank Mme Nadine Boudreau who has been doing a tremendous amount of work on our behalf.

The Department of Fisheries and Oceans does get involved in a number of activities related to development among other things. I say "among other things", because, as you know, we are involved in a great many issues related to the management of fisheries but one area of particular interest is the development of new species, or the better utilization of existing species. Many of you are familiar with the programs, an example being the experimental silver hake fishery that is underway at this very moment. For the first time this year, there is a fishery for silver hake, a resource which, until now, has not been utilized by the Canadian industry. It has been used to some extent by foreigners and hopefully we will be successful in developing this fishery for Canadians. We have done a great deal of work in other areas, such as surimi. As you well know, the surimi industry has grown rapidly over the past few years. Silage is one other area where work

is being done at the moment. I think that the idea of bringing together as many people as possible who are interested in silage along with those who know something about it and who can share their experience will be, for us, an extremely useful exercise.

There is, in this area of Atlantic Canada, a problem disposing of herring carcasses, once the roe has been removed. At the same time there is a developing aquaculture industry which is very aggressive and is growing. Perhaps these two issues could be married together and one way is through silage. Silage does not represent the solution to all the problems, it is not a miracle cure, but it may be one way to help resolve the herring carcass problem.

The silage industry, as you know, has been in operation in Norway for a number of years and today, we will be learning about what has gone on there. There have been problems essentially related to quality but I think they have now been addressed and we will hear how they have been corrected.

In this context I am pleased to introduce the first speaker to you. Mr. Peter Jangaard is our Director of development at the Department of Fisheries and Oceans in the Scotia-Fundy region. Mr. Jangaard, whom many of you know, has been involved in development programs and projects for a number of years and recently was on a fact-finding tour in Norway where he studied the silage industry and prepared a very thorough report.

FISH SILAGE : A REVIEW AND SOME RECENT DEVELOPMENTS

Peter M. Jangaard
Fisheries Development Branch
Department of Fisheries and Oceans
Scotia-Fundy Region
P.O. Box 550
Halifax, Nova Scotia
B3J 2S7

ABSTRACT

A brief review of various enzymatic processes for preserving fish is given with emphasis on Canadian contributions. Recent developments in Norway are described in some detail as a result of a visit to that country in March 1987. These include research and development work on acid fish silage and silage concentrate and their use as a feed especially for salmon and fur animals.

INTRODUCTION

Due to the vagaries of weather, seasons and fish movements, fishermen and processors are often faced with glut situations when prices drop and fish may even have to be dumped. Traditional methods of processing and preservation include drying, pickling, salting and drying and smoking. Canning became possible with the mass production of the tin can and in recent decades, freezing has become the most important method for preserving food fish in developed countries. In a parallel development, fish meal and oil have become important world commodities. Modern fish meal plants have sprung up to process the catches of highly efficient fishing vessels, even in remote areas of countries like Peru and Chile. Fish meal has become an important feed ingredient in rations for poultry and other domestic animals and world meal and oil prices fluctuate with the abundance of competing products like soybean meal and oil and palm oil.

In countries like Norway and Scotland, salmon aquaculture has had an explosive growth in the past decade. Salmon production in Norway increased from 4,000 to 46,000 tonnes between 1979 and 1986. The outlook for 1987 is 53,000 tonnes and for 1988, it is 74,000 tonnes. There are now 690 licensed fish farms and 562 hatcheries in that country.

These salmon, and over 4,000 tonnes of trout, require increasing quantities of good quality feed. A high percentage of the Norwegian fish meal production now consists of special grades of top quality meals for aquaculture and fur animal feeds. These meals are produced from very fresh, chilled raw materials carefully dried in steam dryers; in some cases, even under vacuum (Utvik and Hansen, 1987).

About ten years ago, fish silage was heavily promoted in Norway as a feed that could replace a high percentage of the dry feeds and fresh or frozen fish used by fish farmers. Due to lack of proper quality control, some fish farmers had poor results when they started to feed fish silage. As a result, the growth of the silage industry has now levelled off, although the farms that use fish silage or silage concentrate appear to be satisfied that it is a good and cost-effective feed. Indications are that further growth in the silage industry in Norway will come from increased demand from fur animal farmers.

The roe herring carcass disposal situation in Southwestern Nova Scotia is becoming more and more critical as land based dumping sites are being closed and dumping at sea becomes more difficult and expensive. The large fish meal plants located in the area in the 1960s and 1970s were dismantled and sold abroad. A new meal plant would cost several million dollars to install and there is considerable opposition among the local population to a plant being built in their own neighbourhood based on perceived odour problems.

The Fisheries Development Branch, Department of Fisheries and Oceans, Scotia-Fundy Region, in Halifax, Nova Scotia, decided to look at fish silage as an alternate processing method for herring carcasses and other fish offal ashore and for viscera and by-catches on trawlers. Capital costs for equipment are considerably lower than for a comparable fish meal

plant and there are no odour problems. One disadvantage is that transportation of silage involves large quantities of water, and users should therefore be located as close as possible to the plant. The growing salmon farming industry in the Bay of Fundy area appears to be a ready market for top quality fish silage.

This report reviews various enzymatic processes and discusses the production and utilization of fish silage. A considerable part of the report is based on information obtained by the author during a visit to Norway in March 1987. In order to discuss the problems and opportunities of fish silage production with the fishing industry, this workshop is being sponsored by the Department of Fisheries and Oceans.

HISTORICAL

The word **silage** is derived from **silo**; i.e., material stored in a silo as practised on farms and is not really descriptive of fish silage. A better word to describe fish silage would perhaps be "liquid fish", "liquefied fish protein" or when more concentrated, "protein concentrate". In this report, fish silage is defined as silage produced by adding inorganic and/or organic acids to lower the pH sufficiently to prevent bacterial spoilage. The fish silage becomes liquid because the tissue structures are degraded by a process called autolysis by enzymes naturally present in the flesh.

There are many examples of traditional fish products prepared by controlled autolysis. A brief review of some of these are given in the following.

Salted Products

When salt is used as a preservative to slow or stop bacterial action, enzymatic changes may occur in the fish to give the product unique characteristics. Because fish decompose relatively more rapidly than other animal protein foodstuffs, it was often difficult, especially in hot climates, to arrest all the degradative changes that occur on storage. It was found, however, that when these changes were controlled, desirable flavours were conferred to the product which increased acceptability of the fish or masked less pleasant flavours and odours. The process that induces these changes has been given the name of fermentation (Mackie et al, 1971). Normally, fermentation is taken to mean the transformation of organic substances into simpler compounds by the action of enzymes or micro-organisms. Typical examples of salted products produced or enhanced by

this process are fish sauces, sugar or spice cured Scandinavian herring products and Gaspé cured salt cod in Canada.

The fish sauces are of great importance in countries in Southeast Asia, especially in Vietnam where the product is known as "nuoc-mam". It is a clear liquid, ranging from yellow amber to dark brown and is rich in salt and soluble nitrogen products. The method of manufacture consists essentially of mixing uneviscerated fish with salt in earthenware pots which are then tightly sealed and buried in the ground. After several months, the pots are dug up, opened and the supernatant liquid is decanted. This primitive form of manufacture is common in Vietnam. When "nuoc-mam" is manufactured on a commercial scale, large vats fitted with bamboo taps near the bottom are used. In this latter process, fish and salt are layered alternately, generally four to five parts of salt to six of fish are used. It takes a few months to produce "nuoc-mam" from small fish, but a year or more may be necessary for larger fish. One part of fish gives two to six parts of "nuoc-mam". The undissolved residue is used as fertilizer (Mackie et al, 1971).

Another example of enzymatic action is the ripening or maturing of lightly salted herring or sprats so popular in Scandinavia. Heavily salted herring ripen slowly and do not develop the mature flavours of lightly salted herring.

In the salt curing of cod in some areas, the amount of salt used is only sufficient when coupled with the drying effects of the sun and wind to keep spoilage changes to a minimum, but still permitting some fermentation to take place. A typical example is the "Gaspé Cure" traditionally produced in the Gaspé Peninsula of Quebec (VanKlaveren and Legendre, 1965).

Autolysis by Heating

An alternative method is to carry out the digestion (autolysis) rapidly under optimum conditions for the enzyme and then stabilize the solution against further enzymatic degradation and bacterial decomposition.

In recent studies at the Seattle Laboratory of the U.S. National Marine Fisheries Service, liquefied fish is prepared by heating ground, whole fish to 30-60°C. After liquefaction, the mixture is heated to 85°C to inactivate both proteolytic and lipolytic enzymes, and after, cooling acids are added to prevent spoilage. For example, fresh, ground Pacific Whiting was heated at 60°C for approximately thirty minutes, until liquefied, the temperature increased to 85°C for fifteen minutes

to destroy endogenous enzymatic activity and to pasteurize the liquid. After cooling the liquefied fish to room temperature and screening it to remove the larger bones, 2% phosphoric acid was added to prevent spoilage (Hardy et al, 1984; Stone et al, 1984; Stone and Hardy, 1986).

Autolysis by Enzyme Addition

Since different enzymes attack different parts of the protein molecule, adding commercially available enzyme preparations such as papain or bromelain could possibly change the direction of the reaction, change the optimum reaction temperature or affect the flavour of the final product. When fish viscera are being ensiled, the addition of enzymes will not affect the rate of autolysis (Freeman and Hoogland, 1956). For further information, the reader should consult the following papers: Mackie et al, 1971; Mackie, 1973; Mackie, 1974; Hale, 1969; Raa and Gildberg, 1982.

Lactic Acid Fermentation

One reason fish spoils more quickly than flesh or warm blooded animals is that tissues become less acid **post mortem** in contrast to mammalian tissues. By encouraging the growth of lactic acid bacteria, the spoilage processes leading to the reduction of trimethylamine oxide to trimethylamine and the degradation of amino acids to ammonia by spoilage bacteria are suppressed. Lactic acid bacteria are well-known in dairy products such as yoghurt. Although these bacteria are natural inhabitants of fish, they are present in low numbers. Fish also contains only small amounts of free sugar which is the essential substrate for growth of such bacteria (Raa et al, 1983; Mackie et al, 1971). Therefore, to preserve fish or animal waste products by fermentation, it is essential to add a sugar source, preferably with a starter culture of proper lactic acid bacteria which, by rapid conversion of the sugar to acid, preserves the whole mass. A considerable amount of fermentable sugar must be added to obtain a stable silage with a pH around 4; for example, 20 kg of a dry mixture of malt and oatmeal was required for 100 kg of fresh herring (Nilson and Rydin, 1963) or more than 10% molasses (Roa, 1965). Malt was essential for the preservation with the oatmeal additive because the amylolytic enzymes present in the malt convert the starch to glucose which can be fermented by the lactic acid bacteria. Both spoilage bacteria and lactic acid bacteria will contribute to the initial acid production because the conditions are anaerobic and sugars are available, but growth of the lactic acid bacteria will be favoured as the silage becomes more acidic. If the pH falls to below 4, lactobacilli will become

the predominant organism present and harmful bacteria (coliforms, enterococci, typhoid bacteria and even spores of *Clostridium botulinum*) are destroyed in such a silage (Raa et al, 1983). A semi-commercial batch was successfully produced using whey and molasses as the carbohydrate source (VanWyck et al, 1983).

If oxygen is admitted to any extent, then aerobic micro-organisms such as yeasts may develop. Yeasts are capable of growth at relatively low pH and utilize carbohydrate and protein. Mold spoilage may also be a problem, especially if any drying occurs, for instance at exposed surfaces (Mackie et al, 1971).

Although the lactic acid process has been the subject of several patents (Carl, 1952; Ehler and Mikkelsen, 1959) and numerous publications, it has not become a commercial success. A company in Tromsø, Norway, called BIOTEC Ltd. has developed a protein concentrate aimed at the fur animal market, but is not yet in commercial production. The aim was to market a product that can easily be incorporated into feeds for mink and foxes and yet retain the desirable characteristics of lactic acid fermented fish. The fish is therefore heat treated first to deactivate thiaminase and other enzymes and to stop microbial activity; fat can be removed by a decanter and formic acid, molasses and antioxidants added. When cooled, the lactic acid bacteria and finally a binder meal are added to give the product its desired consistency. It is claimed that the product can be stored for several months, that the lactic acid bacteria also acts as an antioxidant and that the flavour is superior to the bitter taste of acid silage. Feeding trials with mink were very positive and encouraging (Berg, 1985).

During the author's visit to Tromsø in March 1987, a meeting was held with Dr. Terje Strøm, Managing Director and Knut Eirik Andersen, Division Manager of BIOTEC Ltd. Dr. Strøm was formerly the Director of the Tromsø Technological Laboratory of the Norwegian Institute for Fisheries Technological Research (FTFI). This is a new, modern laboratory with extensive pilot plant facilities and a staff of some 60 scientists, engineers and other professionals (Figs. 1, 2). In close cooperation with Dr. Jan Raa and his group at the Fisheries Institute, University of Tromsø, a number of new processes for utilizing resources have been developed (see references). As these processes move towards commercial utilization, the highly trained scientists and engineers at FTFI are snapped up by private industry. How commercially successful these biotechnology companies will be, remains to be seen.

A meeting was also held with Dr. Raa and his staff and his pioneering work with fish silage was discussed.

This author has been in close contact with the research and development community in Tromsø for a number

of years and will be pleased to provide further information to those interested.

Figure 1.
*Institute for Fisheries
Technological Research,
Tromsø. N.K. Sørensen,
P. Eng., in foreground.
University of Tromsø is
nearby.*



Figure 2.
*Pilot plant at Tromsø
Lab. The Swanson
Process (FIDECO) for
fish protein being tested
in enclosure in back.*

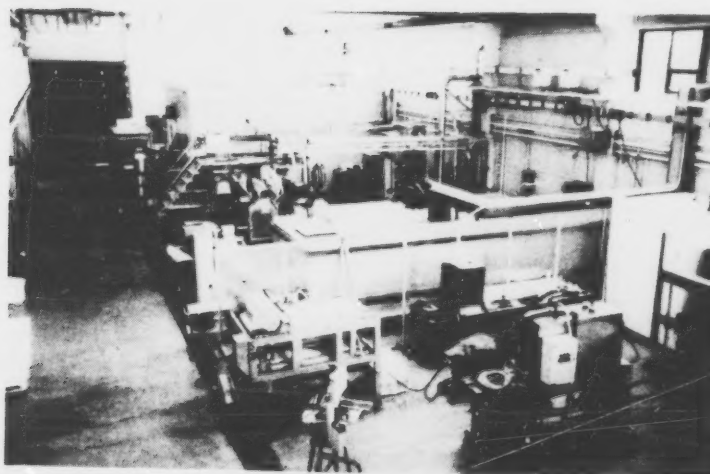


Figure 3.
*Dr. T. Strøm and K.E.
Andersen of BIOTEC
with N.K. Sørensen of
FTFI.*



Fermentation by Proteolytic Fungi and Yeasts

Some traditional Japanese food products are produced through the action of specific fungi and several studies with fish as raw material have been reported (Mackie et al, 1971).

Bertullo and Hettick (1959) have developed a method of preparing a fish protein hydrolysate using a proteolytic yeast *Saccharomyces platensis proteolytica*. A fermentable sugar is added to the minced fish and the mixture is inoculated with the yeast culture. Fermentation is complete in eight days and, after centrifugation to remove the bones and oil, the hydrolysate is concentrated by low temperature evaporation and spray dried. This process has recently been resurrected and promoted by a consultant in the United States, and the author was recently approached to participate in a large scale feasibility study for Atlantic Canada. Additional information, such as feeding trials with humans and animals, is available from this author.

Acid Silage

As mentioned above, the name silage is derived from the process of storing chopped up green plants such as grass, oats or corn, without drying, in a silo. An anaerobic fermentation process takes place and acetic and lactic acids are produced. These acids act as preservatives and the proteins present are largely hydrolyzed. In the 1920s, a Finnish professor, A.I. Virtanen, made the process more reliable by adding mineral acids to lower the pH in the mixture, since many crops may not have enough starch or sugar for natural fermentation.

In 1936, experiments were started in Sweden with the A.I. Virtanen (AIV) process for preservation of fish and fish offal intended for use as animal feeds. Results of the trials were published by Edin (1940) and Olsson (1942). The Swedish experiments included, besides the AIV process (Hydrochloric + sulphuric acids) two other acid preservation methods: the Sulphuric Acid/Molasses Method and the Formic Acid Method (H. Petersen, 1953).

The chief advantage of AIV acid over organic acids is its low cost, but this is probably outweighed by the disadvantages in that it is a highly corrosive liquid producing a corrosive product which requires neutralization. Most of this work in Sweden was carried out immediately preceding the Second World War. With the outbreak of the war, hydrochloric acid became very scarce and Olsson, looking for other

preservatives, tried formic acid. He found that this acid limited the growth of bacteria at a relatively high pH (4.0) as compared to mineral acids like sulphuric acid (pH 2) and that no neutralization was necessary before feeding the silage to animals.

The Danish Fisheries Technological Laboratory started work on fish silage, and at the same time an industry was started for the production of fish silage for animal feeding (H. Petersen, 1951; H. Petersen, 1953; P. Hansen, 1959). In the late 1970s, the commercial fish silage production in Denmark was about 60,000 tonnes a year.

A considerable amount of research and development work was carried out in Great Britain in the 1970s and a seminar on fish silage was held at Torry Research Station, Aberdeen in 1976. Tatterson and Windsor (1974) reviewed the literature and described experiments with six types of silage from various raw materials. Storage stabilities and compositions were determined and they found rapid deteriorative changes in the fish oils and increases in soluble nitrogen. The changes taking place in silages prepared from different parts of the fish were studied by Backhoff (1976). He found that the enzymes mainly responsible for the liquefaction were those of the gut, skin and other parts of the fish, rather than those of the flesh. Reece (1981) studied ways of improving the quality of oil recovered from silages and suggested that hydrogen peroxide addition could inhibit pigmentation and reduce the free fatty acid content.

A series of studies of silages prepared from fish viscera were carried out in Tromsø, Norway by Raa and co-workers (Raa and Gildberg, 1976; Ström and Eggum, 1981; Stormo and Ström, 1978; Gildberg and Raa, 1977). This work has led to the establishment of several biotechnology companies such as Marine Biochemicals Ltd., who are marketing Pepsin and Peptone from cod viscera, and the above mentioned BIOTEC Ltd.

An interesting report on the preparation of silage from seal carcasses was published by Stormo (1983). Seal silage was tested as feed for mink and found to be satisfactory (Skrede, 1983).

In recent years, much of the work in Norway has been centered on the use of fish silage and fish silage concentrate as salmon and mink feed and on quality aspects. These studies will be discussed later.

Work in Canada on acid fish silage was carried out at the Halifax Technological Station of the Fisheries Research Board of Canada by Freeman and Hoogland (1956 a, b). These scientists described the production

of silage from fish viscera using sulphuric acid (5 lbs. conc. H_2SO_4 per 100 lbs. cod and haddock offal (viscera)). Feeding tests with chickens and hogs were also carried out (Haskell et al, 1959, Cameron, 1962). In another paper, systematic studies on the effect of pH and enzyme addition were carried out. It was found that the rate of digestion of cod and haddock viscera at 15°, 25° and 37°C was not affected by the addition of proteolytic enzymes; apparently, sufficient amounts of enzymes were available in the raw material. The effect of pH between 1 and 8 on the extent of the digestion was negligible; however, at high pH (6.5 to 7.5), samples of viscera rapidly produced very offensive spoilage odours. At pH 3 or below, no spoilage occurred. The rate of autolysis increased with temperatures from 15°C to 37°C and reached a maximum after three days at 37°C. Three methods of drying were tested; vacuum, spray and drum drying and good end products were obtained with all three methods.

At the Vancouver Technological Station of the Fisheries Research Board of Canada, similar work was being carried out on Pacific herring (Tarr et al, 1953; McBride et al, 1961). Three methods were tested to liquefy the whole herring; acid silage, high pressure steam liquefaction and proteolytic enzyme solubilization. Both mineral acids at pH 2 and formic acid at pH 4.5 were tested and feeding tests with chickens carried out. These authors found that liquefaction of the fish in an acid medium was achieved in 72 hours at 37°C. Also in Vancouver, B.C., a study was carried out at the British Columbia Research Council Laboratory on silage from dogfish wastes such as skin, head and viscera without livers (Strasidine and Jones, 1983). The authors found that by adding 1.5% formic acid and heating to 45°C, almost complete liquefaction was achieved in 24 hours. The silage was low in some essential fatty acids, and rat feeding tests indicated that the silage had high digestibility, but a reduced biological value compared with fish meals or silage from white fish or herring.

Silage from fresh water species was investigated by Ward et al (1985) at the DFO Laboratories in Winnipeg, Manitoba. A processing facility was constructed and processing costs calculated.

In recent years (1980s), the Province of Nova Scotia Department of Fisheries supported the construction and operation of a small fish silage plant at Casey Fisheries in Victoria Beach, Nova Scotia. Silage from this plant has been used for feeding trials with pigs at The Agriculture Canada Research Station in Nappan, Nova Scotia. Both straight and dried silage have been tested as a fertilizer on vegetable crops at the

Kentville, Nova Scotia Research Station of Agriculture Canada. These trials are continuing (Blatt, 1983, 1984, 1985, 1986).

In Prince Edward Island, Winter and Javed (1983) have been promoting the use of fish silage and have carried out feeding trials at the Agriculture Canada Research Station in Charlottetown. A silage plant was constructed and operated at the Acadian Fishermen's Co-Operative in Abram Village, Prince Edward Island and in a comparative study with Memorial University, St. John's, Newfoundland, formaldehyde (0.25% or 0.39% by wt) was added to fish silage to stop further autolysis before feeding tests with ruminants were carried out (Haard et al, 1985).

In Quebec, fish silage studies are underway as a cooperative effort between The Food Sciences and Technology Department at Laval University, Quebec City and the Quebec Department of Agriculture Fisheries and Food in Gaspé.

ACID SILAGE PRODUCTION

Plant and Equipment

The basic equipment for an acid silage plant is quite simple and could be assembled from food processing equipment readily available. However, it is important for a plant of any size to have at least automated acid addition with a pH meter downline controlling the rate.

It is claimed that it is better to stop the autolysis soon after liquefaction to cut down on bitter flavours (peptides), fat autolysis (free fatty acids) and complete protein autolysis to amino acids. It might therefore be desirable to have a heat exchanger and holding cell to be able to heat the silage to 85°C or so and hold it to inactivate enzymes. The next step would be to add a decanter/separator to remove the oil from the silage. The last scenario, and of course the most expensive, would be to have an evaporator to produce silage concentrate.

A simplified sketch of a basic silage plant is shown in Figure 4. The raw material is brought to a feeding hopper with a screw feeder on the bottom.¹ Formic acid (and antioxidant) held in an acid tank² of suitable resistant material (fiberglass or plastic coated, etc.) is fed to the fish with a metering pump³ before the grinder⁴, thereby ensuring good mixing of acid with the fish. The fish should be ground so that no pieces are larger than 3 - 4 mm in diameter (Tattersson, 1976). The mass is then pumped in a Progressive Cavity Pump (Mono pump)⁵, where acid and fish are further

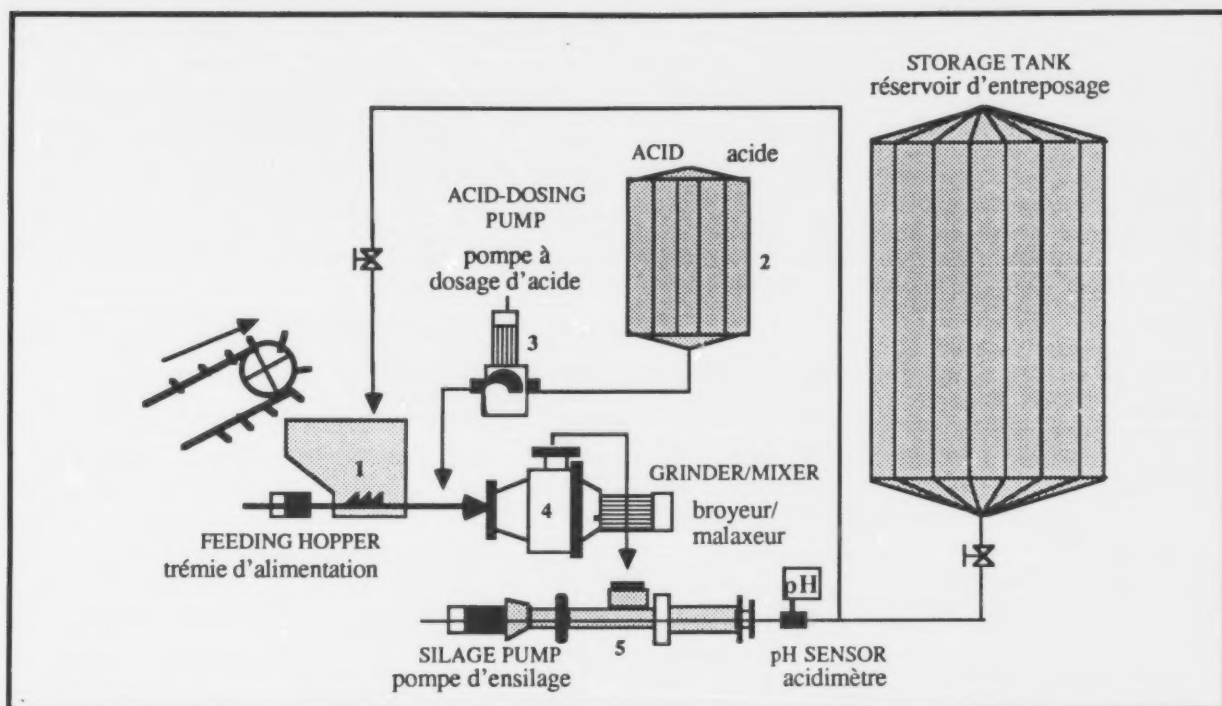


Figure 4: Typical acid silage installation. Courtesy Senta Ltd., Hamar, Norway

mixed. A pH meter in the line adjusts the addition of acid automatically, or stops the plant, if the pH is not in the desired range (3.8 - 4). A similar layout is available for shipboard installation and close to twenty have been installed onboard trawlers and purse seiners in Norway over the past 6 - 7 years (Viken and Björge, 1987).

An interesting adaptation of silage is the seal carcass silage plant onboard a vessel and described in a report by Stormo (1983). The reason for starting this project was a ban on leaving seal carcasses on the ice in the "East Ice" within the Soviet Economic Zone. After the pelts with blubber had been removed, and perhaps some meat to be frozen, the rest of the carcass had to be disposed of.

A "seal chopper" was constructed from a massive steel disc (1.5 m x 4 cm) with four knife blades attached. A counterknife was fastened on the

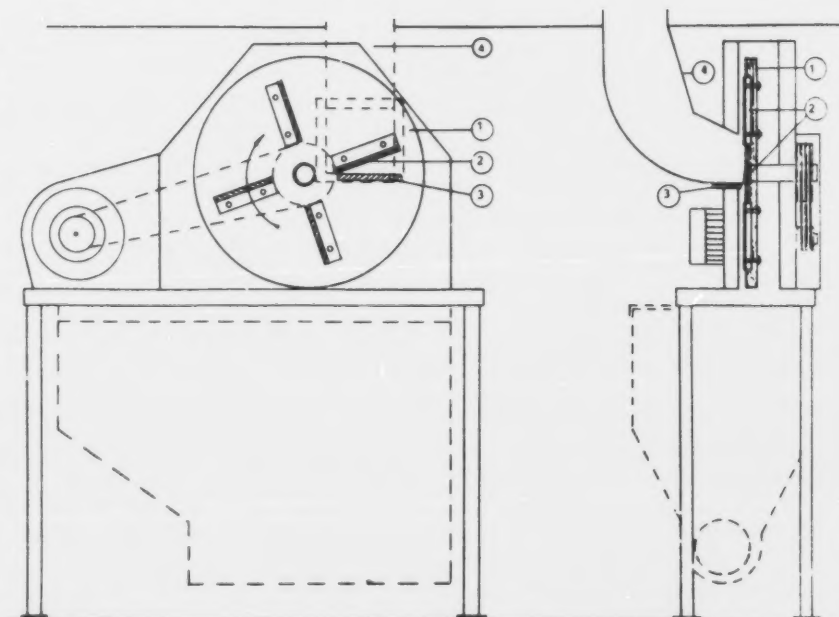
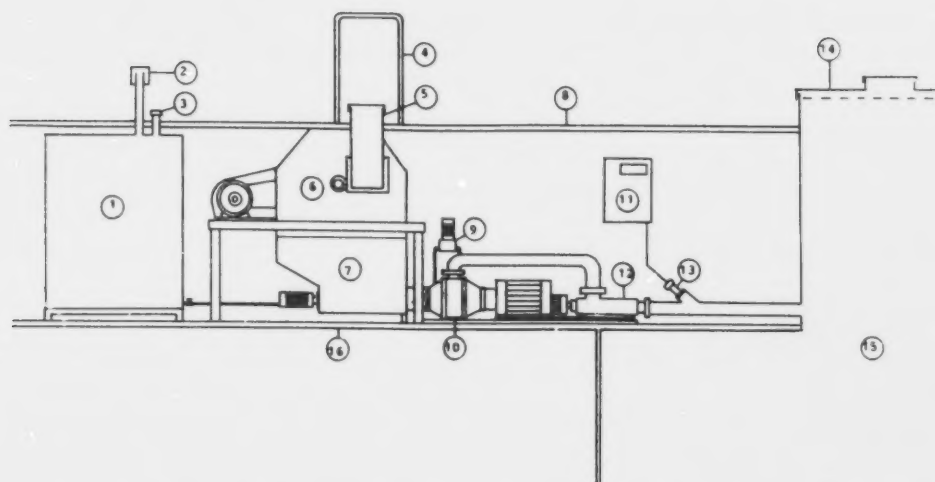


Figure 5. "Seal Chopper" 1. Massive, Rotating Disc, 2. Knives, 3. Counter-knife, 4. Inlet Tube

fixed plate giving a scissorlike action as the disc was rotated. A seal carcass was chopped up in 3-4 seconds in this contraption, and the knives did not have to be replaced or sharpened even after 4500 seals had been processed (Fig. 5).

The first year there were serious problems in moving the mass after acid addition since it turned practically solid. The silage plant was modified, pipes made larger and provision made to add silage to the freshly chopped material. After these modifications, there were few problems in producing silage (Fig. 6).

Fig. 6: Seal silage plant onboard S/V Kvitbjörn



- | | | | |
|---------------------|-------------------|-----------------------|----------------|
| 1. Acid Tank | 5. Feeding Chute | 9. Acid Metering Pump | 13. pH-Control |
| 2. Air Vent | 6. Chopper | 10. Grinder | 14. Tank Hatch |
| 3. Filling Pipe | 7. Feeding Hopper | 11. Control Panel | 15. Tank |
| 4. Protective Guard | 8. Shelter Deck | 12. Product Pump | 16. Main Deck |

The seal silage was tested in feeding trials with mink and salmon and found to be a fully satisfactory feed (Skrede, 1983).

A complete evaporation plant for the production of silage concentrate is, of course, considerably more complicated and expensive and only two are in actual production in Norway (Royal Seafood Ltd., Bjugn, Trondheim and Rieber and Co., Tromsø). A schematic layout of a plant producing basic silage, pasteurized silage, silage concentrate and oil is shown in Figure 7.

The evaporation part is the most expensive and involves sophisticated vacuum evaporators with

automatic control equipment. In the Royal Seafood Ltd. plant in Bjugn, Norway, the silage is first heated to 95°C, passed through a decanter and centrifuge to separate oil and sludge (Söbstad, 1987). The water phase is passed through a flash evaporator at 55°C where it cools to 35°C, is reheated and flash evaporated again until the solid content reaches 50-55%. A second effect evaporator operating at 35° and lower vacuum makes the system more energy efficient (Figures 8, 9).

Figure 7. Courtesy Royal Seafood, Trondheim, Norway

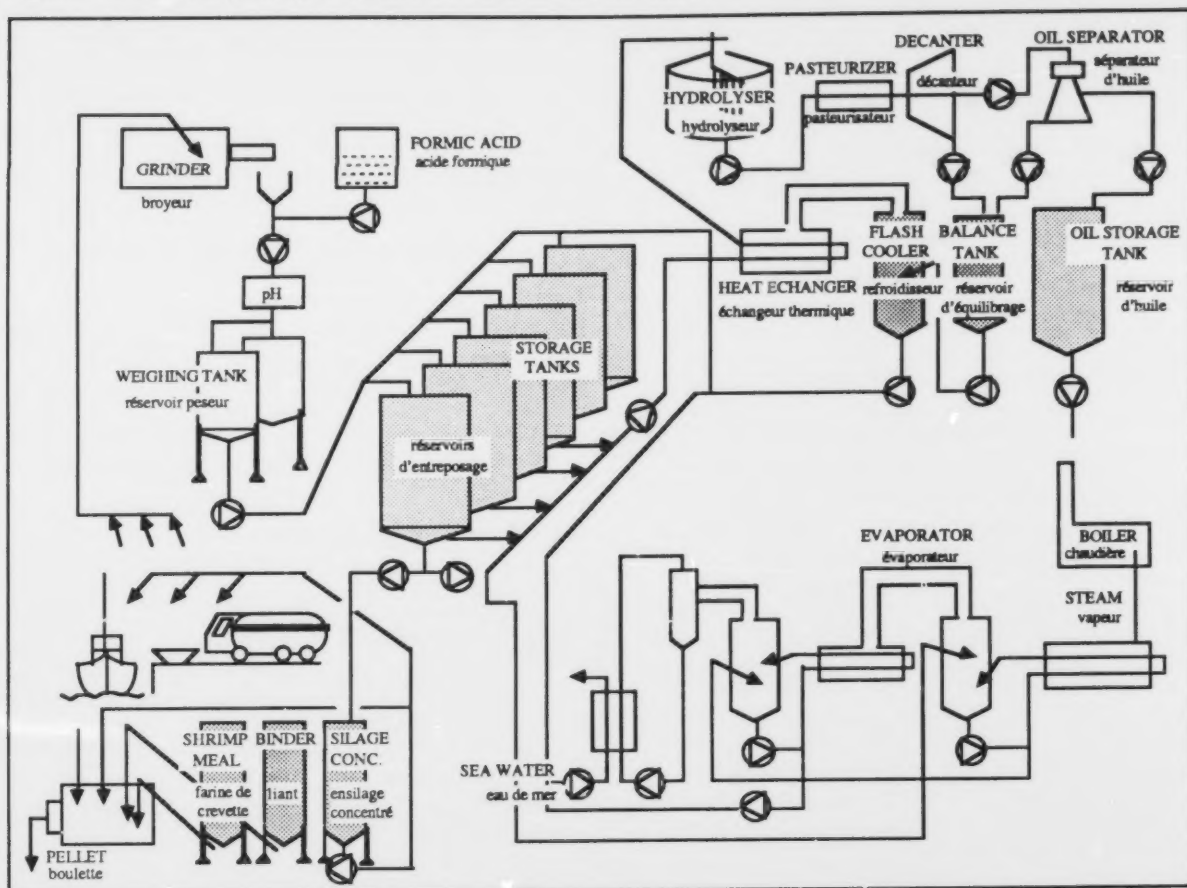


Figure 8. Flash evaporator at silage concentrate plant at Bjugn (Royal Seafood A/S).

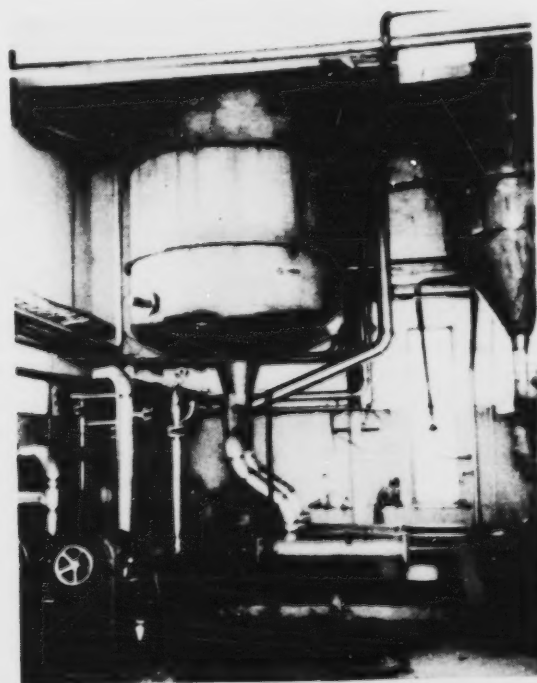


*Figure 9.
Control panel at
silage concentrate
plant in Bjugn.*

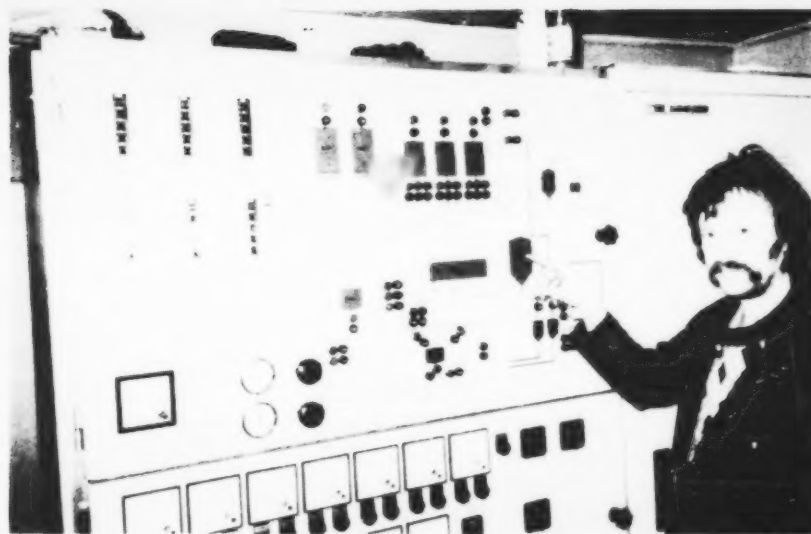
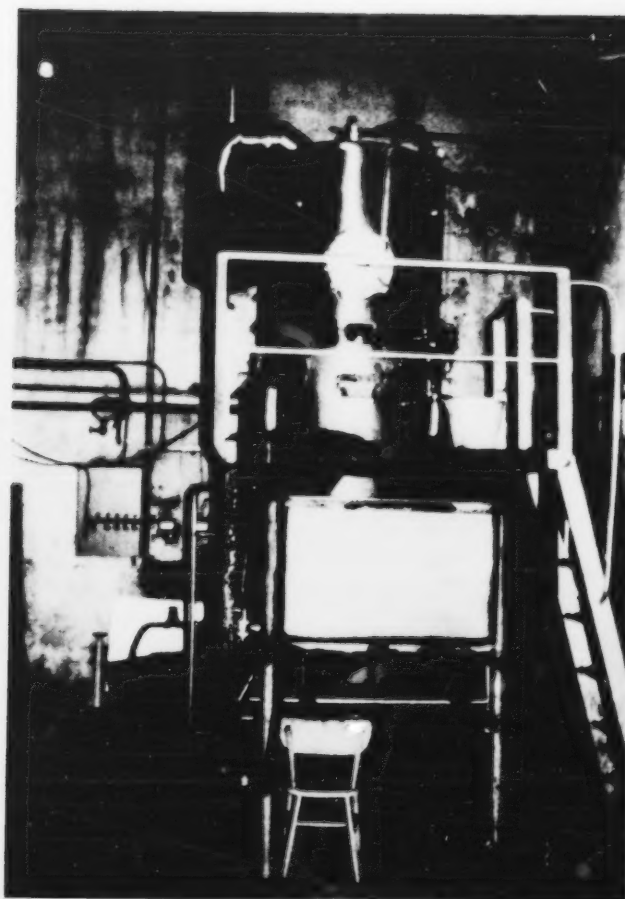


*Figure 10.
Silage concentration
plant at Rieber Co. in
Tromsø.*



The Rieber plant in Tromsø operates with a forced circulation evaporator, but is presently planning to expand with new equipment (Fig. 10). Two large equipment manufacturers for the fish meal industry, Stord Bartz, Bergen and Hetland Process, Sandnes, also manufacture evaporation systems for stickwater that can be modified to handle silage.

Another interesting silage process was also developed in Tromsø; namely, ensiling shrimp waste for use as a source of pigment for salmon and trout. The shrimp waste from peeling machines is first dewatered in a twin screw press (Stord Bartz, Type TP-24-2CP) yielding a product with 45% solids. This can be preserved by a mixture of concentrated phosphoric acid (5% v/w), 50% sulphuric acid (10% v/w) and propionic acid (10% v/w) containing ethoxyquin (0,1 0/00) as the antioxidant. No microbial growth including molding occurred when stored in plastic bags at ambient temperatures for six months. Feeding tests with salmon and trout showed that the acids used did not negatively affect the nutritional quality of the meal.

Although these experiments seemed to be very successful, very little, if any, ensiled shrimp waste was

being used in 1987 in Norway, probably because of the amount of acid in the product. It is now more common to use shrimp meal dried under very mild conditions to preserve the natural colour compound astaxanthin.

The Process

In order to have control over the manufacturing process and the product, it is necessary to understand the changes taking place in the silage during manufacture and storage.

Protein Changes

The muscles and skin of fish consist largely of protein. There are many types of protein depending on the function it fulfills in the fish, from collagen in the skin to myosin in the muscle. Common to proteins is that they are composed of about 20 different amino acids in various complex combinations, sometimes several hundred of each. Amino acids are linked together in long chains called peptides and these are crosslinked to form the complex network of peptides that make up a protein. The simplest peptide, a dipeptide, consists of two amino acids linked together.

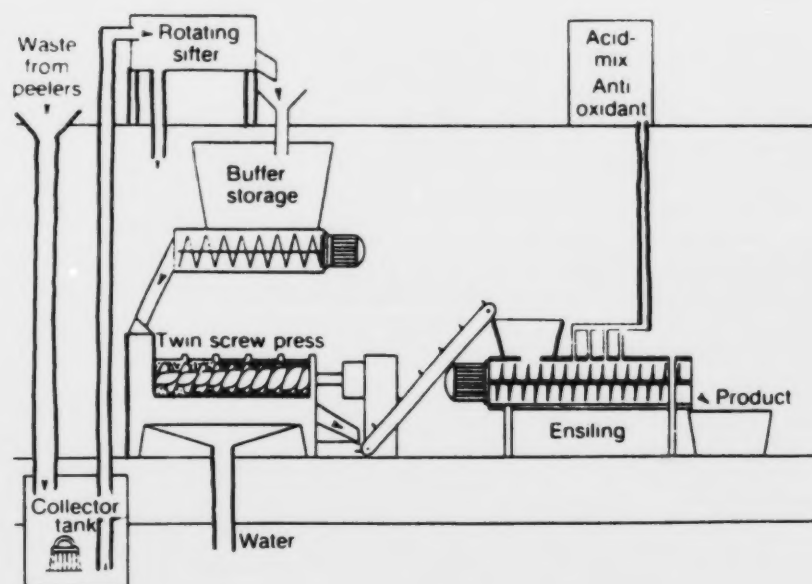


Figure 11. Production line for shrimp waste.

An enzyme is a complex protein with a prosthetic group attached which enables the enzyme to initiate or speed up chemical reactions. Enzymes control most chemical processes in living tissues and each enzyme has a specific function. Enzymes can be inactivated by heat and by certain chemicals.

The enzymes of importance in silage are various proteinases that break down proteins into peptides and individual amino acids and lipases that break down fats into free fatty acids and glycerol.

A silage gradually liquefies as connective protein tissues are broken down by enzymes in the fish and become water soluble. This self-digestion is called autolysis and the rate is dependent on the activity of digestive enzymes in the raw material, the physiological condition of the fish when caught, the pH, the temperature and the preservative acids.

In order to determine which fish tissues had most enzyme activity, Backhoff (1976) made silage from various parts of cod that had been carefully dissected. As shown in Figure 12, the enzymes mainly responsible for liquefaction were from the viscera, skin and other parts of the fish other than flesh which showed very little proteolytic activity at pH 3.9.

It should be noted that in Figure 12 and in some other similar graphs, the left axis depicts "percent soluble protein", or "percent non-protein nitrogen", not when silage "becomes liquid" or "pumpable". In practical terms, if so desired, the reaction could be stopped much earlier than at the point of maximum protein solubility and still be a liquid silage. The type of raw material used and the reaction temperature are the two most important determinants.

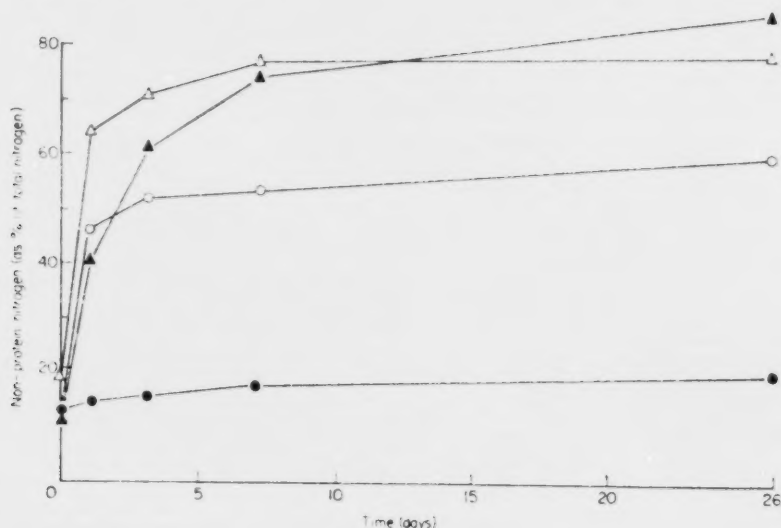


Figure 12. Formation of non-protein nitrogen in silages produced from different parts of cod at pH 3.9 and 30°C. (Δ) Silage from gut; (O) silage from skin; (▲) silage from head; (●) silage from flesh. (Backhoff, 1976)

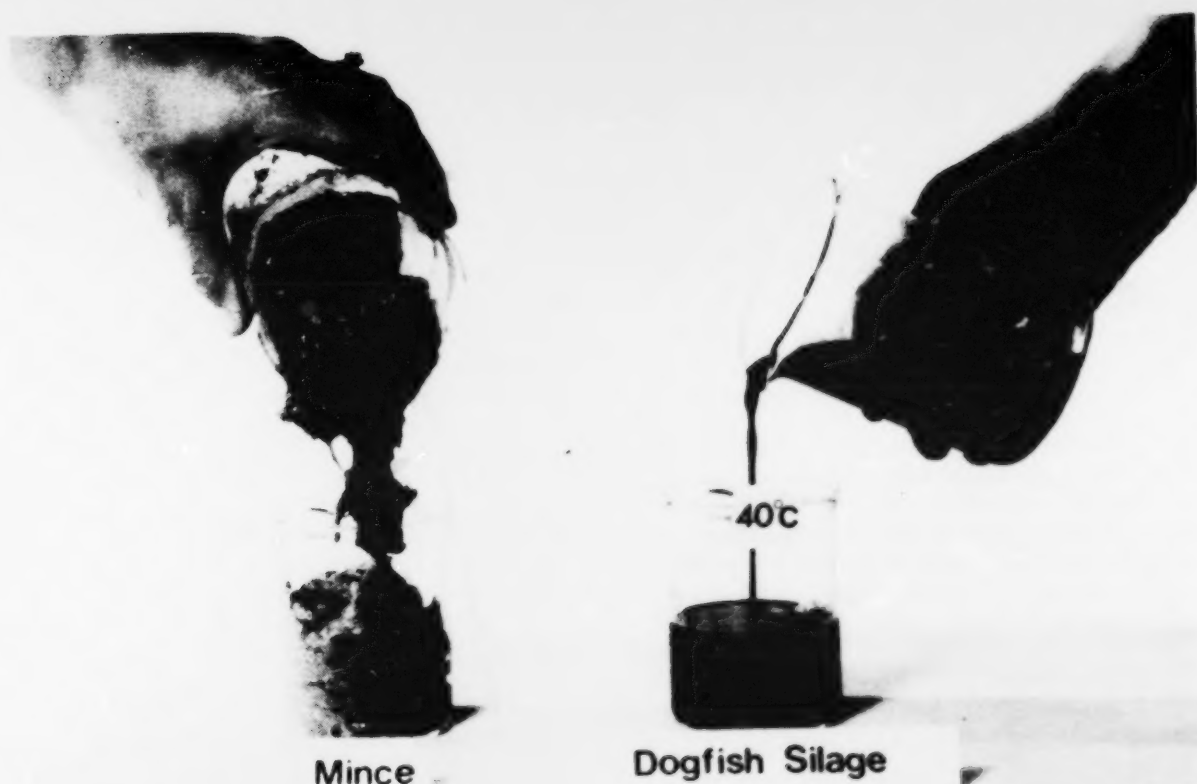
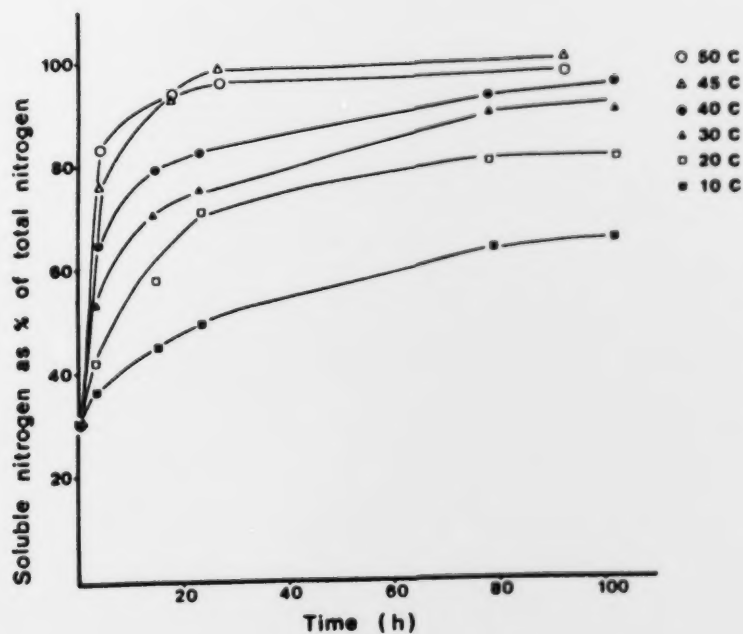


Figure 13. Ground dogfish offal and liquid silage following 24 h digestion with 1.5% formic acid at 40°C. (Strasdine and Jones, 1983)



The effect of temperature on dogfish offal silage is shown in Figure 14. Comparing this figure with Figure 13, it can be seen that the liquid silage in the photograph would have roughly 80% of its protein in a soluble form.

Figure 14. Autolysis of dogfish silage as a function of temperature. (Strasdine and Jones, 1983)

It can be seen from Figure 15 that the rate of autolysis at temperatures below 10° is quite low. This must of course be taken into consideration when designing a plant for the climate found in Atlantic Canada.

As autolysis progresses, oil will be liberated and float to the top and bone fragments and undissolved tissues go to the bottom. It is important that a means of stirring the silage in the tank is provided for. There will always remain a fraction of the protein which is resistant to enzymatic digestion. The reason is not completely known, but it may be that the rate of reaction becomes very slow when the most favourable binding sites or splitting sites have been used up.

One drawback of acid fish silage is that the product often has a bitter flavour that could have an effect on animal acceptability of the product. It is difficult to assess how serious this problem actually is with salmon since the author has not seen documented studies. However, it was mentioned a number of times during

my visit to Norway in March 1987, that bitter flavours increase on storage.

When autolysis is carried out in a strong salt solution as in the production of nuoc-mam, or in many of the fermentation type processes mentioned above, the bitter flavours are not produced. Several authors have linked the bitter flavours to certain types of polypeptides formed as the protein molecules are broken down in the autolysis.

In a recent study, Stone and Hardy (1986) studied the formation of peptides and free amino acids in silages kept at pH 2 and pH 4, both prepared with sulphuric acid. Figures 16 and 17 show that the formation of peptides and free amino acids proceed quite differently at the two pH levels. At pH 4, the polypeptides are broken down into free amino acids on storage while at the lower pH, they remain as peptides. These authors also discussed the possibility of using various processes to control the end products in silages to suit the nutritional requirements of a variety of aquatic and terrestrial species.

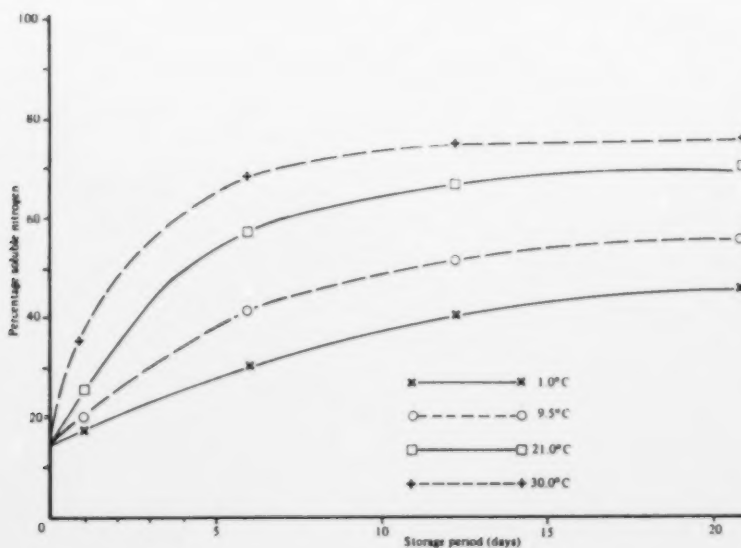


Figure 15: Soluble nitrogen as a percentage of total nitrogen during storage of sprat silage at various temperatures (Tatterson, 1976).

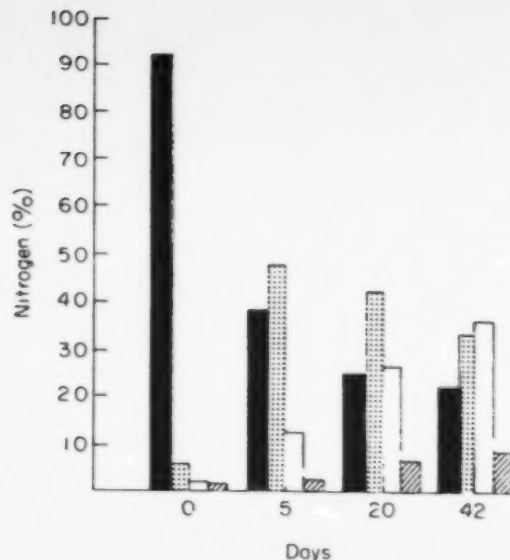


Figure 16: Protein autolysis of fish silage at pH 4.0 stored for 42 days at room temperature: (■), TCA (10%) insoluble; (●), polypeptides; (□), free amino acids; (▨), ammonia. (Stone and Hardy, 1986)

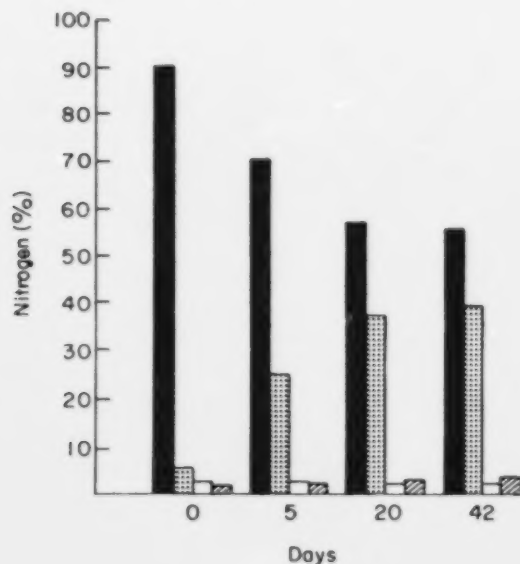


Figure 17: Protein autolysis of fish silage at pH 2.0 stored for 42 days at room temperature: (■), TCA (10%) insoluble; (●), polypeptides; (□), free amino acids; (▨), ammonia.

Bitter peptides are also produced when vegetable proteins are hydrolyzed. Japanese and American workers have shown that the bitter flavours disappear by the use of a procedure called the Plastein Reaction. It is not known if this procedure could become economically feasible (Fujimaki et al, 1970; Onoue and Riddle, 1973).

Although bacterial activity is practically stopped in a silage of proper pH, in formic acid silages, and especially in fermented silages, there can still be some ammonia formed. This is the result of enzymatic degradation of amino groups in some amino acids, but it does not appear to be serious enough to reduce the nutritional value of the silage (Raa, 1982).

Lipid (Fat) Changes

Among the enzymes active in a silage are also lipases that will break down lipids to free fatty acids. There are also free fatty acids in the digestive tract of some fish liberated from fatty acid salts in an acid medium (Reece, 1980, 1981).

Figures 18 and 19 show how the free fatty acid content increased over a 20-day period in sprat and mackerel silage and Figure 20 looks at changes over an extended storage period at different temperatures. It appears as if the rapid rise in FFA in sprat in Figure 18 was caused by a very active lipase system in these fish. It would appear likely that FFA formation would be enhanced if actively feeding fish were ensilaged. In Figure 20 it can be seen that the reaction again is definitely temperature dependent.

Reese (1981) also found that the colour of oil recovered from silage was very dark and related to blood pigments (haemin) in the fish. He suggested the use of hydrogen peroxide to inhibit oil pigmentation and to reduce the FFA content in the recovered oil.

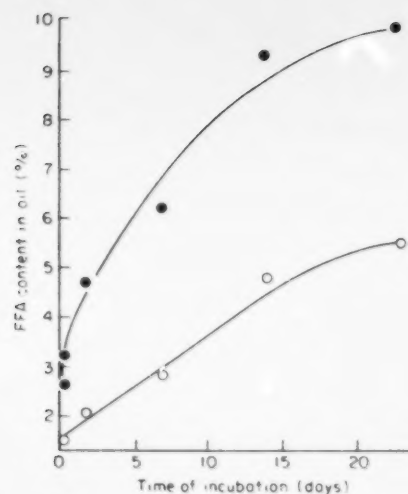


Figure 18. Increase of FFA in (○), mackerel; and (●), sprat silage oils.

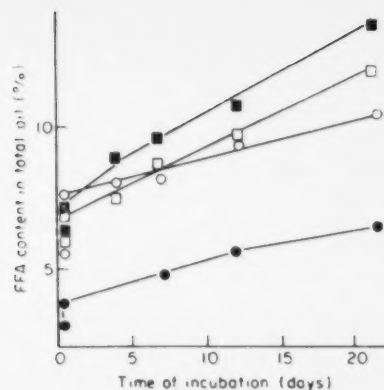


Figure 19. Effect of fish guts on the hydrolysis of oil in mackerel and sprat silage. (○), whole mackerel; (●), gutted mackerel; (□), gutted sprat; (■), whole sprat. (Reece 1981)

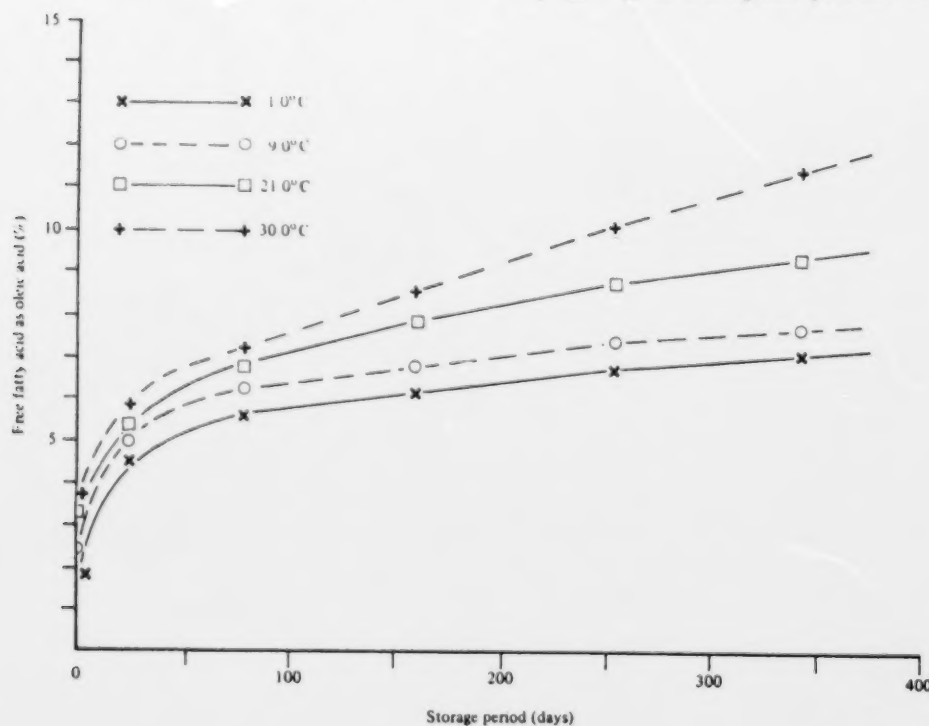


Figure 20. Free fatty acid content of extracted oil during storage of sprat silage. (Tatterson 1976)

More serious from the point of nutrition is oxidation of the fat in the silage. Salmon and mink are especially sensitive to oxidized fats, and an antioxidant should therefore be added to the silage. Common practice in Norway is to add the antioxidant to the formic acid (200 ppm ethoxyquin). An inert gas (CO₂, N₂) could also be used over the silage in the storage tanks. If the silage is to be used to feed livestock, it is better to remove the oil as soon as it is feasible and store it separately.

The Product

Quality and Analytical Methods

One reason for the slow growth of the fish silage industry in Norway after the initial optimism is inconsistent quality (Pedersen, 1987). The author points out that many thought that the silage process could be used to "rejuvenate" poor quality raw material. As a result some users were "turned off" by silage and must be convinced that a product of uniform quality and with guaranteed product specifications is available to them.

As a result of these concerns, a working group has been formed in Norway to establish quality standards for fish silage. The group is coordinated by Mr. O. Pedersen of the Pelagic Fish Marketing Board in Trondheim and the seven other members represent Government Fish Inspection Service, Research Laboratories, processors-fishermen and user organizations.

So far, the group has issued a proposed Product Declaration form to accompany all silage shipments and also an Ensilage Journal. The use of a product declaration is not yet required in Norway, but it is just a question of time before a regulation will be in place. A product declaration should contain information of value to the user and it is recommended that users be skeptical towards shipments with no documentation. After all, fish become "unidentifiable" after being ensilaged and the user should know the raw material used.

Sampling is also very important since, unless the silage is well stirred and mixed, there can be an oil phase, an aqueous phase and a bottom layer of undissolved bones, etc.

The working group has done much work on suitable analytical methods that will define the quality and value of the silage. Samples were submitted to a number of laboratories, but the results showed that there are still problems with analytical methods such as those for fat content and fat rancidity.

For formic acid silage, the pH is recommended to be between 4.0 and 4.3. If pH is above 4.5, there is the danger of bacterial activity, decomposition and perhaps formation of toxic compounds. The pH value is not constant and should be checked regularly, especially when the silage is freshly produced, the temperature is high or the ash or bone content is high. Silage from fish and fish products has a certain buffering action. This means that relatively large quantities of formic acid can be added without the pH dropping correspondingly. It is therefore of interest for the user to find out how many kilos have been used per tonne raw material. When formic acid alone is used, the pH should not be below 3.8. The lower the pH, the better the storage ability. The higher the pH, the less acidic the finished feed will be. There has to be a balance between the two (Pedersen, 1987).

The group has recommended that in addition to protein and fat, both ash and dry matter (not fat-free solids) be given. The reason for this is to be able to have a certain control over how well fat and protein analyses were carried out by the laboratories. Since % protein + % fat + % ash = % dry matter, it is then possible to double check if the protein, and especially the fat analyses, are correct. The value for ash will indicate if the silage was made from whole fish, mostly viscera or bony offal. The ash content of whole fish is usually in the 2-3% range.

Many users believe that a thicker fish silage contains more nutrients than a thin, more liquid, silage. The "thickness" or viscosity of fish silage is more dependent on the temperature that the silage was produced and stored. The higher the temperature, the more liquid the silage. A thin silage can therefore easily contain more nutrients than a more viscous product. It is often more important for the user that the silage is well stirred and not separated into layers.

The concept of the term quality is difficult to define. In commercial terms, it is often limited in the case of fish silage to pH and the contents of protein, fat, dry matter and ash. Many different parameters have been evaluated and have also been tried in other countries. Some of them are as follows.

Total volatile nitrogen, trimethylamine oxide, trimethylamine, biogenic amines, free fatty acids, peroxide value, anisidine value, total oxides, antioxidant residue, thiaminase activity, total bacterial count, various/specific bacteria, number of yeast spores. Which parameters to include in a quality standard is dependent on how reliable they are, what they really tell us, time to carry out analyses, how many laboratories can carry them out and how important they

are in a commercial context. Furthermore, the total analytical costs should not be so high that they, in practice, are not being performed. By using these criteria, the group has proposed the following analyses for a quality standard for silage fish and fishery products:

1. Total volatile nitrogen (Tot. Vol N)
2. Trimethylamine nitrogen (TMA-N)
3. Trimethylamine oxide nitrogen (TMAO-N)
4. Peroxide value
5. Total bacterial count less than 100,000 per gram
6. Total number of fungi/mold, fewer than 5,000 per gram

The group is not yet finished with their work and hope to come up with definite maximum values for the other analytical criteria (Pedersen, 1987).

Trimethylamine (TMA) is the decomposition product of trimethylamine oxide (TMAO). For simplicity, only the nitrogen from these compounds is analysed and designated as TMA-N and TMAO-N. The amount of TMAO-N in fish varies, dependent on fish species, from about 1% to 4% of total N. It has been found that the value of TMA changes little after ensiling. TMA is chiefly formed through bacterial decomposition of TMAO. When acid is added, the bacteria are inactivated or killed and the TMA level is therefore quite stable. The content of TMA-N therefore indicates how fresh the raw material was when it was ensiled. Since the TMAO-N content varies so much, it is necessary to compare the TMA-N to TMAO-N. The percent TMA-N of TMAO-N + TMA-N will therefore give a good measure of the bacterial activity in the raw material before preservation. It should be noted that silage from sharks like dogfish will always have a higher content of total Vol N since 20-30% of the N can be urea-N.

Another potential problem with quality control of fish silage is to determine from the silage which species have been used. A study was carried out at the Central Laboratory of the Directorate of Fisheries in Bergen (Gjerde and Sayed-Ahmed, 1985).

The water soluble proteins from silage were analysed by isoelectric focusing. Eight different species were included in the study and the silages were stored at 10°C for 22 days. Each species had differing protein patterns that could be clearly distinguished from each other. However, after 20 days of storage the patterns became so weak that it was difficult to identify individual fish species. The method can therefore only be used if there is maximum two species in the silage and one of these must comprise at least 20% of the total.

A study on the fat quality of silage was carried out in Denmark by Lund and Hölmer (1978). They found that the fatty acid composition did not change in the short term. However, free fatty acids and peroxide values were much higher in silage than in the frozen control.

UTILIZATION OF FISH SILAGE

In Agriculture

The original use for fish silage was in agriculture as feed for livestock and Olsson in his 1942 paper described feeding experiments with chickens. Since then, there have been numerous studies worldwide describing the use of silage for livestock and no attempt will be made in this paper to cover this literature in detail. In an excellent review on fish silage, Raa and Gildberg (1982) surveyed the literature on the nutritional value of acid-preserved fish silage. They state that most feeding experiments with acid-preserved fish silage show that it is a good source of protein and that its nutritional value is comparable to that of fish meal when included in cereal rations for animals. Specific beneficial effects of silage have been reported. However, some reports show that silage is inferior to fish meal, in particular in poultry diets.

Raa and Gildberg further state that there are some distinct limitations to the use of fish silage in animal rations. Firstly, the very acid (pH 2 to 3) silage produced with sulphuric acid must be neutralized before it is fed to animals. Secondly, at high inclusion rates in the final feed, fish silage may cause reduced feed intake and growth. Thirdly, to avoid carcass off-flavours, the inclusion rate should be adjusted so that the fish fat (lipid) level in the complete diet does not exceed 1% of the dry weight. A more exact criteria of the tendency to cause carcass taint would be the content of polyunsaturated fatty acids.

A number of references are quoted by Raa and Gildberg to the effect that feed conversion efficiency and daily live weight gain of pigs fed a cereal diet with fish silage supplement are equal to fish meal and significantly better than soy protein diets. Many reports agree that pigs grew faster and consumed less feed per kilogram of growth when fed on a silage diet than on a diet enriched with the same quantity of milk protein or of soya bean meal enriched with lysine. Farmers using Danish fish silage have claimed that it improved fertility of animals. Although there have also been reports on the slightly inferior nutritional quality of fish silage as pig feed, it seems safe to conclude that fish silage is a high quality protein additive in pig rations (Raa and Gildberg, 1982).

In feeding trials with pigs fed silage from cod and haddock viscera at Nappan, N.S., rate of gain, feed efficiency and carcass characteristics indicated that the product was a satisfactory source of supplementary protein (Cameron, 1962; Freeman and Hoogland, 1956). However, a moderate off-flavour was detected in the meat from pigs fed fish silage to market weight.

In a more recent study on chickens, Kroghdahl (1985a, b) found that chicks fed viscera silage diets performed as well as, or better than, chicks fed the control diet. However, in broilers as little as 1.5% fat in the silage rendered the meat unacceptable in trials when silage comprised up to 40% of dietary crude protein.

The use of silage for mink feed in Scandinavia has been on the increase in recent years. A. Skrede and co-workers at the Institute for Poultry and Fur Animals, Norwegian Agricultural College, has shown in a series of experiments that silage is a good feed for mink and foxes. A series of trials in 1984 with formic acid silage from herring offal with mink, blue fox and silver fox gave positive results with the use of 23% silage.

In a more recent study, silage concentrate was tried in a series of experiments with blue fox and mink (Skrede, 1986). The feed was found to be fully acceptable and performed as well or better than the control feed.

Danish studies (Woller) show that care must be taken in preventing the formation of histamine if the silage is to be used for mink. Since histamine is formed if fish such as mackerel or herring are kept at room temperatures for some time, it is important that silage is only prepared from fresh, chilled fish.

In Aquaculture

The largest growth in the use of fish silage in recent years has been in Norway where it is used to feed salmon. It also seems that the greatest opportunity to market fish silage from roe herring carcasses would be to the growing salmon farming industry in the Bay of Fundy area.

Experiments with silage in diets for salmonids started at the Norwegian Institute of Aquaculture Research in 1977. When the experiments were started, several questions needed to be answered. Which acids would preserve feeds efficiently? Would the fish accept an acid-preserved diet? How would the health of the fish be influenced by such a diet? How would the quality of the product be affected? Diet consistency would have to be determined. Which raw materials would be suitable for acid preservation? (Austreng and Aasgaard, 1986).

In the 1977 experiments the silage was mixed with 10% binder meal (W/W) before being fed to the fish, and as the silage liquefied after autolysis, the feed consistency became too soft to be properly used as feed. The feed was easily dissolved in the water, resulting in large feed losses. Both rainbow trout and salmon grew well on the silage, but not as well as fish fed frozen feed. The reason for the difference was presumably due to the problems with feed consistency. A special binder meal for silage was therefore prepared from herring meal, cooked wheat, vitamins, minerals and a special binding component consisting of alginate and guar gum. These ingredients produced a sufficiently firm moist pellet when mixed with the silage at a ratio of between 35:65 and 50:50 (W/W) dependent on the silage (Austreng and Aasgaard, 1986).

In 1979 five silages which had stored well were tested in a growth experiment and compared to a frozen fish control diet. The silage was prepared from trash fish with a high fat content. It was mixed in a 55:45 ration with the binder meal prior to feeding. Both rainbow trout and salmon grew well on all diets except those containing propionic acid. Those made with 2.2% (W/W) formic acid and 2.5% sulphuric acid +1.1% formic acid led to very favourable weight increases. After the fish had been fed a few weeks they stopped eating those feeds containing propionic acid.

Silage made from dogfish offal (2.5% formic acid) was also tested and compared with frozen dogfish offal and frozen trash fish. The fish grew well on all diets without significant differences. Although the level of fluoride in the offal was high, it did not cause elevated fluoride levels in bone, skin or meat of the slaughtered fish.

In cooperation with the Svanøy Foundation, Svanøybukt, Norway, an experiment was started in 1980 to analyse possible long-term effects of diets containing silage. The rainbow trout used in the experiment were slaughtered in December 1981 and the salmon in June 1982. The fish were fed diets containing silage from mackerel offal (frozen control) during a period starting shortly after the transfer of fish to sea water until the termination of the experiment. Acids used for the preservation of the diets were formic acid (2.5% W/W) or sulphuric acid (2.5%) plus formic acid (0.5%).

All groups were in the same condition of health. The first year the salmon had a similar growth rate, but the control group for the rainbow trout showed about 10% higher weight gain than the other test groups. One factor that may have influenced the fish silages negatively was that the mackerel offal had been frozen

prior to acid preservation. Austreng et al (1979) have shown that trash fish was more difficult to preserve when it had been frozen for five days. The consistency of the moist pellet was better with the silage than with the frozen fish. With silage about 30% less feed was used for the same weight increase.

Silage has also been used in the diets for brood stock at the Institute of Aquaculture Research. The diet composition varied, starting with a moist pellet with about 40-50% binder meal, 20-40% frozen fish and 15-30% silage from fish offal. This has been the practice since May 1980 with good results. Starting in September 1982, all frozen fish in the diet was replaced by silage. Feed consistency has been improved and feed losses reduced. About the same amount of dry matter has been used per kilo weight increase of fish by this moist pellet as by using dry feeds. The silage has been easy to handle and labour saving and the price of the feed reasonable relative to the cost of other feeds of current interest (Austreng and Aasgaard, 1986; Austreng, 1979; Austreng, 1980). It was also shown by Austreng and Gjefsen (1981) that fish grow well on diets with large amounts of free fatty acids as found in some silages.

A massive feeding experiment with large salmon was carried out under the auspices of the Institute for Nutrition of the Norwegian Directorate of Fisheries at Bjugn near Trondheim in 1984-85 (Lie et al, 1986). Although the objective of the study was to determine if there was any connection between feeding and the so-called Hitra-disease (cold water vibriosis), a large body of important data has been accumulated. The control feed consisted of soft pellets made from silage and binder meal with 44% metabolizable energy from protein and 35% from fat. Eight other diets were made from the control plus various additives such as Vitamin E, selenium, Vitamin C and methionine, from evaporated silage and a commercial dry feed. A total of about 6,000 salmon were used and some 150,000 analytical data and observation recorded. Both straight silage and silage concentrate were found to be fully satisfactory feeds and none of the diets had any effect on the outbreak of Hitra disease (Anon. 1987).

During my visit to Norway in March 1987, several users of silage were interviewed.

Halsa, a three-hour drive south of Bodø in Helgeland County, Northern Norway is the home of Torris Products Ltd., one of the largest salmon producers in Norway (close to 1,000 tonnes a year). They are large users of silage concentrate brought in by vessel from the Royal Sea Food plant in Bjugn. They also have a silage plant and in another location, a large fish meal plant.

The silage concentrate is pumped from tanks to feed mixers where binder meal, shrimp meal, vitamin mix, etc., are added. The mixture is extruded into pellets of a size suitable for the fish being fed and automatically dispensed by water to the various pens. The whole operation is controlled by a computer. The company also has a hatchery with a licensed capacity of 500,000 smolts/year. The processing plant has large smokers, modern shrink plastic wrapping machines and freezers and cold storage facilities. Fresh, frozen and smoked salmon is exported worldwide; Japan has become an important market for fresh salmon in the past year or so. The product manager, Rolf Torrisen, was very pleased with the silage concentrate and the flavour of the smoked product was superb!

In Aalesund, Mr. Bjorn Fladmark of Aarsaether Brothers Ltd. was interviewed. This is one of the largest integrated fishing companies in Norway with a number of plants producing frozen fillets, shrimp, salt fish, stock fish, cod liver oil, etc. At the salmon farm near Aalesund they use 20-30% silage in their feed which they produce themselves or bring in by vessel from Florø/Maløy to the south. They now have silage plants onboard their newest trawlers, and will be utilizing this silage in their salmon feed. In the winter they also use some cod liver oil from their own production instead of the usual capelin oil.

A visit was also made to Austevoll outside Bergen to the large feed producer Austevoll Fiskeindustri. This company produces 3 - 3,500 tonnes of feed a year and transport the pellets or dough with their own vessel to many of the 20 salmon farmers in the area. They have their own silage plant (Sotra Rustfri Industri) and purchase some silage from herring filleting plants for a total usage of about 600 tonnes/year. The feed is typically made from 19-20% silage, 2% frozen shrimp meal, vitamins, etc. At the time (March 1987) they were selling soft pellets for N. Kr. 3.90/kg. (\$0.78/kg) and dough for N. Kr. 3.60/kg (\$0.72/kg). Dry feed costs were N. Kr. 6.70/kg. and binder meal close to 7 kr/kg, according to Mr. K.A. Gloppen, the plant manager.

Discussions were also held about the "Bjugn Project" with Drs. Njaa and Lambertsen at the Directorate of Fisheries Nutrition Institute in Bergen. The importance of antioxidants was stressed, since oxidized fat can affect flavour (aldehydes), irritate the stomach and perhaps be toxic. Ethoxyquin is used for silage in Norway, the same antioxidant used for fish meal worldwide. It was said the ethoxyquin is not permitted in the U.S.; other antioxidants possible are gallates, hydroxyquinone, BHA, BHT and anisole.

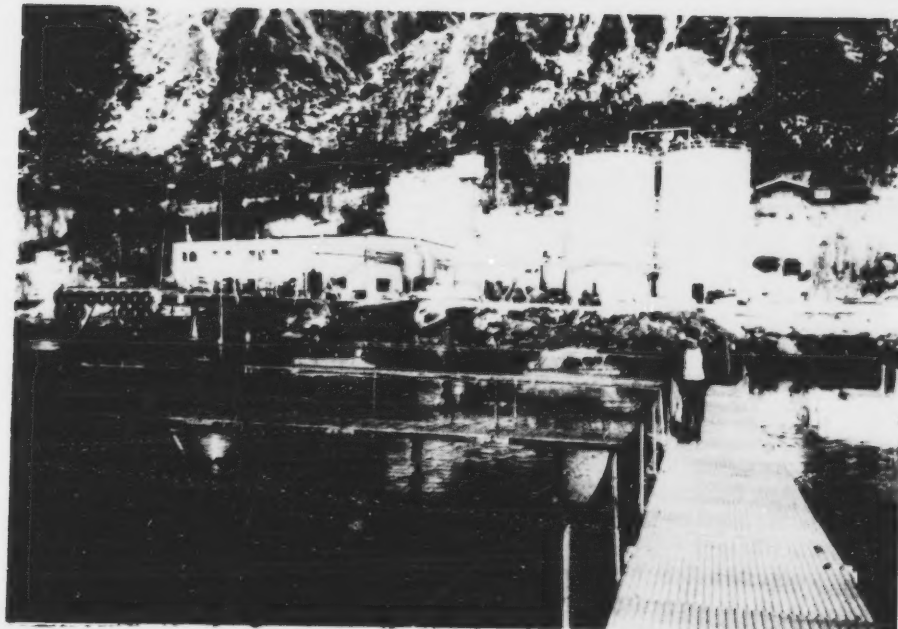


Figure 21. Some of the salmon pens at Torris Products Ltd., Halså, Helgeland. (Mr. Rolf Torrissen, Product Manager). Note tanks for holding silage concentrate, binder meal, etc.

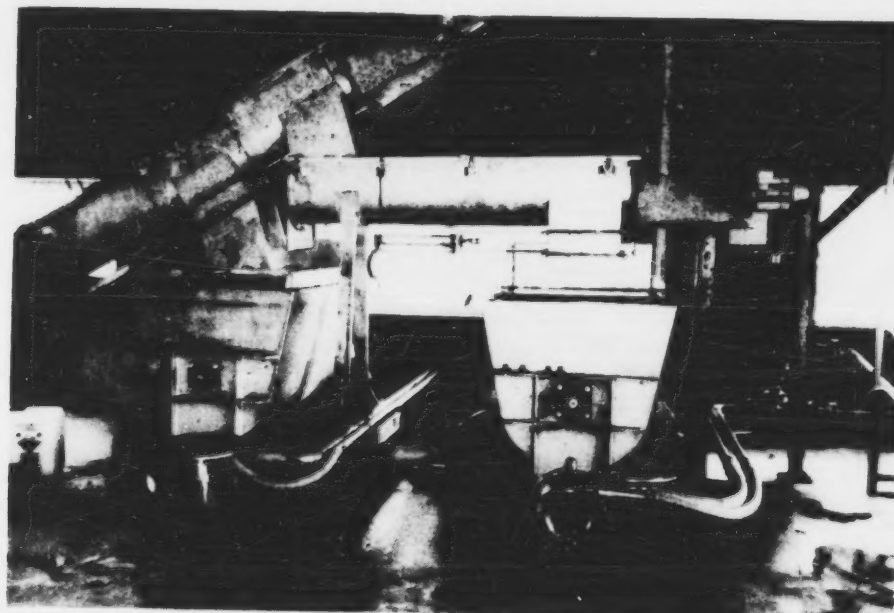


Figure 22. Pellets are flumed to individual pens under control of a computer at Torris Products, Ltd.

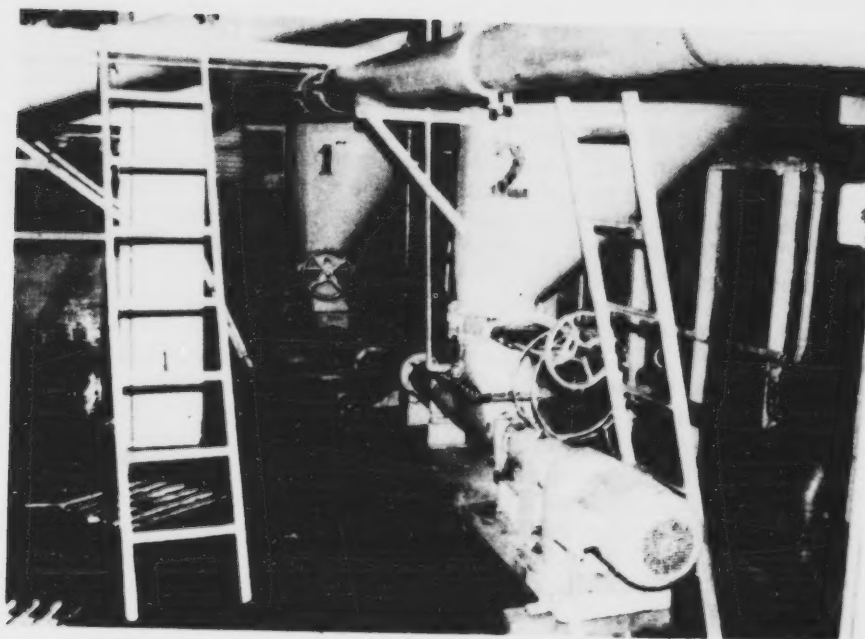


Figure 23. Part of fish silage plant, Austevoll Fiskeindustri.

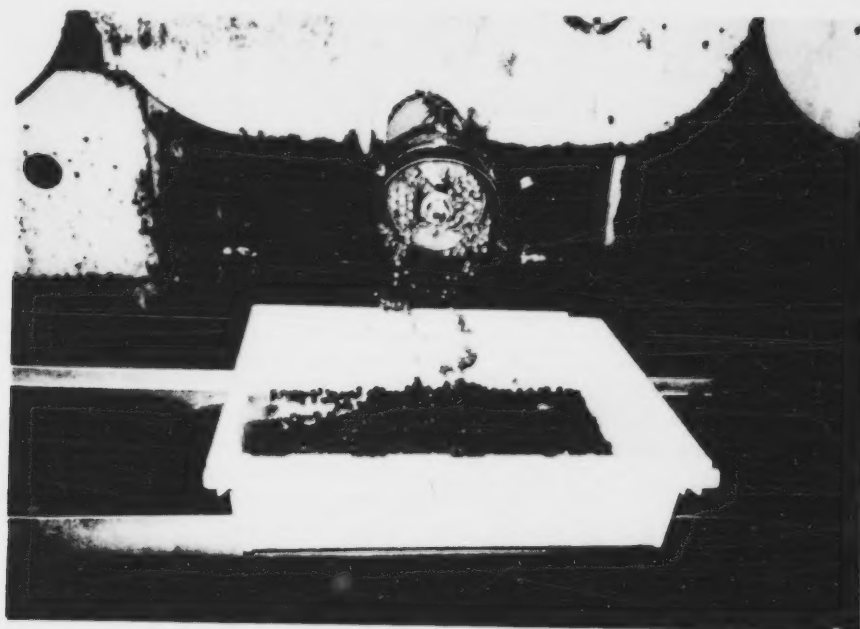


Figure 24. Pellets made from 19-20% silage, Austevoll.

Since practically all silage storage tanks in Norway are steel (not coated) some high values for iron had been noted in some silages and should perhaps be watched. The Director of the Institute, Dr. Njaa is also on the same quality working group as Ove Pedersen, and we had further discussions on the difficulty of developing meaningful analytical methods for silage.

The Institute is now working intensely on determining the nutritional requirements of the next fish species to be farmed, namely cod and halibut. At Austevoll, the Institute of Marine Research Experimental Station was visited and second generation halibut and third generation cod observed.

As Fertilizer

Fish silage could also find use as a fertilizer, and trials with various vegetables on different types of soil have been underway for several years at the agriculture Canada Research Station, Kentville, N.S. (Blatt, 1983-85). This work is sponsored by the Province of Nova Scotia, and work is also under way on a spreader.

It is possible that concentrated silage could be used as a fertilizer for house plants similar to the fish fertilizer solutions now brought in from British Columbia and Alaska. Under the Sea Grant Program, studies have been carried out at Virginia Tech. and other American universities using stickwater concentrate from fish meal plants with promising results.

CONCLUSIONS

The lesson learned from the history of fish silage in European countries is that **quality and marketing** are two of the keys to a successful industry. If these two criteria are carefully addressed, fish silage could certainly play an important role in solving or minimizing the herring carcass problem in the Bay of Fundy area.

Before anyone decides on investing in a fish silage plant, capital and operating costs must be carefully considered. Potential customers are salmon and trout farmers, mink and fox farmers and poultry, cattle and pig farmers within a certain distance from the plant. Transportation of 70 - 80% water is expensive.

Each group of users will require a different product. For poultry, cattle and pig feed, the silage should be de-oiled so the fat content is as low as possible.

Mink and fox farmers must be assured that the fat has not been oxidized and that there is no histamine or thiaminase in the silage. This might require heating

and/or de-oiling. Since most mink farmers in Nova Scotia have freezers and prepare their own feed, it might be difficult to penetrate this market.

Salmon farmers can use silage with a high fat content, but the fat must be protected with an antioxidant. All users can only use silage prepared from fresh, good quality raw material.

Since the salmon aquaculture industry in Atlantic Canada is concentrated in a relatively small area in the Bay of Fundy, a silage delivery system using tankers or seiners with RSW tanks may be economically feasible.

It is hoped that this workshop will act as a catalyst to bring potential silage producers and users together and that some developments will take place in the not-too-distant future.◊

REFERENCES

- Anon., 1986. Irish Food Suppliers. Aquaculture Ireland, No. 27: 10-11.
- Anon., 1987. Hitra-sjuka skuldast ikkje manglar ved føret (The Hitra-disease is not caused by deficiencies in the feed). Fiskets Gang 73(3): 101-102. (In Norw.)
- Austreng, E., 1980. Syrekonservering av for til fisk (Acid preservation of feed for fish). Norsk Fiskeoppdrett 5(5): 4-6 (In Norw.).
- Austreng, E. and T. Aasgaard, 1986. Fish silage and its use. Proc. 2nd Int. Conf. Aqua farming, "Aquacultura '84", Verona, Italy: 218-229.
- Austreng, E. and T. Gjelsen, 1981. Fish oils with different contents of free fatty acids in diets for rainbow trout fingerlings and salmon parr. Aquaculture 25: 173-183.
- Austreng, E., A.E. Andersen and A. Skrede, 1979. Syrekonservering av forfish (Acid preservation of fish for feed). Norsk Fiskeoppdrett 4(1): 4-7 (In Norw.).
- Backhoff, H.P., 1976. Some chemical changes in fish silage. J. Fd. Technol. 11: 353-363.
- Blatt, C.R., 1983-86. Fish silage as fertilizer for vegetables. Ann. Reports 1983-86. Agric. Canada, Kentville, N.S. Res. Sta.

Burkholder, L., P.R. Burkholder, A. Chur, N. Kostyk and O.A. Roels, 1968. Fish Fermentation. Food Tech. 22: 1278-1284.

Berg, H., 1985. Försök med Ensi-Ferm, Värmebehandlat mjölksyrabakterie fermenterad fiskeensilage (Trials with Ensi-Ferm, heat treated, lactic acid bacteria fermented fish silage). Finnish Fur Animal Laboratory, Vasa. Manus, September 1985. (In Swe.)

Bertullo, V.H. and F.P. Hettich, 1959. Protein hydrolysis by yeast. U.S. Patent 3.000.789.

Cameron, C.D.T., 1962. Acid fish offal silage as a course of protein in growing and finishing rations for bacon pigs. Can. J. Animal Sci., 42: 41-48.

Carl, L.K., 1952. Method for preservation of feedstuff. Danish Patent Appl. No. 3415/50.

Edin, H., 1940. Undersökningar angående importavstängningens äggviteproblem (Studies on the protein problem due to the stop in imports). Nord. Jordb. Forsk. 22: 142. (In Swe.)

Ehlert, H.M. and I.H. Mikkelsen, 1962. Process for treating oil-containing animal material, such as fish and fish offal. Can. Patent No. 646.684, August 14, 1962.

Freeman, H.C. and P.L. Hoogland, 1956a. Acid ensilage from cod and haddock offal. Prog. Rep. Atlantic Coast Stations, Fish. Res. Bd. of Canada (65): 24-26.

Freeman, H.C. and P.L. Hoogland, 1956b. Processing of cod and haddock viscera: 1. Laboratory Experiments. J. Fish. Res. Bd. of Canada 13(6): 869-877.

Fujimaki, M., M. Yamashita, S. Arai and H. Kato, 1970. Enzymatic modification of proteins in foodstuffs. Agric. Biol. Chem. 34(9): 1325-1337.

Gildberg, A. and J. Raa, 1977. Properties of a propionic acid/formic acid preserved silage of cod viscera. J. Sci. Fd. Agric. 28: 647-653.

Gjerde, J., P.D. Iversen, S.O. Roald, R. Thunold, O. Christensen, W. Jacobsen and J. Aarland, 1985. Committee report on technological and safety aspects of installing equipment for acid preservation of fish and fishery products onboard fishing vessels (In Norw). Norw. Directorate of Fisheries, Bergen. Manus. 18 p.

Gjerde, J. and S. Sayed-Ahmad, 1985. Identification of fish species in fish silage. Central Laboratory, Dir. of Fisheries, Bergen. Report, 14 p. (In Norw).

Haard, N.F., N. Kariel, G. Herzberg, L.A. Woodrow Feltham and Karl Winter, 1985. Stabilization of protein and oil in fish silage for use as a ruminant feed supplement. J. Sci. Food Agric. 36: 229-241.

Hale, M.B., 1969. Relative activities of commercially available enzymes in the hydrolysis of fish protein. Food Technol. 23(1): 107.

Hansen, P., 1959. Ensilering of fisk og fiskeaffald (Ensilage of fish and fish offal). Meddr. Fisk Minist. Fors Lab. Denmark, May 1959, 26 p. (In Dan)

Hardy, R.W., K.D. Shearer, F.E. Stone and D.H. Wieg, 1983. Fish silage in aquaculture diets. J. World Maricul. Soc. 14: 695-703.

Hardy, R.W., K.D. Shearer and J. Spinelli, 1984. The nutritional properties of co-dried fish silage in rainbow trout (*Salmo gairdneri*) dry diets. Aquaculture 38: 35-44.

Haskell, S.R., G.I. Pritchard, L.B. Newman, D.A. Shearer, C.D.T. Cameron and W.J. Pigden, 1959. Flavour studies on pork from hogs fed fish silage. Can. J. Animal Sci. 39: 235-239.

Jensen, P.M. and G. Jørgensen, 1975. Production and use of fish silage for mink. Beretn. Statens Husdyrbrugsfors (Den) 427: 79 p. Chem. Abstracts 83: 386.

Krogdahl, Ashild, 1985a. Fish viscera silage as a protein source for poultry. I. Experiments with layer-type chicks and hens. Acta Agric. Scand. 35: 3-23.

Krogdahl, Ashild, 1985b. Fish viscera silage as a protein source for poultry. II. Experiments with meat-type chickens and ducks. Acta Agric. Scand. 35: 24-32.

Lie, O., K. Sandnes, R. Waagbø, K. Julshamn, G. Lambertsen, E. Lied and L.R. Njaa, 1985. Ernaering og Hitra syke. Bjugn prosjektet, et foringsforsök med stor laks (Nutrition and "Hitra-disease"; The Bjugn Project, feeding trials with large salmon). Norw. Dir. Fish. Inst. Nutrition, Bergen, 146 p. + Tables + App. (In Norw.)

Lund, Pia and G. Hölmer, 1978. Undersögelse af fiskeensilage og foderblanding (Studies of fish silage

- and feed mixtures, fats and fatty acids). Dansk Pelsdyravl: 252-254. (In Dan.)
- Mackie, I.M.**, 1973. Potential production of powdered and liquid fish products for human consumption and animal feed. FAO Tech. Conf. on Fish. Prod., Tokyo, 11 p.
- Mackie, I.M.**, 1974. Proteolytic enzymes in recovery of proteins from fish waste. Proc. Bioch.
- Mackie, I.M., R. Hardy and G. Hobbs**, 1971. Fermented fish products. FAO Fisheries Reports, No. 100, 54 p.
- March, B.E., J. Biely, J.R. McBride, D.R. Idler and R.A. MacLeod**, 1961. The protein nutritive value of "Liquid Herring" preparations. J. Fish. Res. Bd. Canada 18(1), 1961.
- McBride, J.R., D.R. Idler and R.A. MacLeod**, 1961. The liquefaction of British Columbia herring by ensilage, proteolytic enzymes and acid hydrolysis. J. Fish. Res. Bd. Canada 18(1): 93-112.
- Nilsson, R. and C. Rydén**, 1963. Fermentation as a means of preserving organic materials. Acta Chem. Scand. 17: 174.
- Olsson, N.**, 1942. Experiments on fish preservation and utilization as feed for hens and chickens. Lantbrukshögskolan Husdjurförsöksanstalten Report No. 7, 1942. 55 p. (In Swedish).
- Onoue, Y. and V.M. Riddle**, 1973. Use of Plastein Reaction in recovering protein from fish waste. J. Fish. Res. Bd. Canada 30(11): 1745-1747.
- Pedersen, O.**, 1987. Fiskeensilasje og kvalitet, varedeklarasjon og kvalitetsstandard. I and II (Fish silage and quality, product specifications and quality standard. I and II). Norsk Fiskeoppdrett, 12(2): 74-76 and (3): 50-51 (In Norw).
- Petersen, H.**, 1953. Acid preservation of fish and fish offal. FAO Fish. Bull. 6(1-2): 1-9.
- Petersen, H.**, 1951. Ensilering af fisk og fiskeaffald. Meddelelse fra Fiskeriministeriets Forsøgslaboratorium, Copenhagen (In Danish).
- Raa, J. and A. Gildberg**, 1976. Autolysis and proteolytic activity of cod viscera. J. Fd. Technol. 11: 619-628.
- Raa, J. and A. Gildberg**, 1982. Fish silage: A review. CRC Critical Reviews in Food Science and Nutrition, 14: 383-419.
- Raa, J., A. Gildberg and T. Ström**, 1983. Silage production, theory and practice. In: Upgrading waste for feeds and food. Butterworths: 117-132.
- Reece, P.**, 1980. Control and reduction of free fatty acid concentration in oil recovered from fish silage prepared from sprat. J. Sci. Food Agric. 31: 147-155.
- Reece, P.**, 1981. Recovery of high quality oil from mackerel and sprat by the silage process. J. Sci. Food Agric. 32: 531-538.
- Roa, P.H.**, 1965. Ensilage of fish by microbial fermentation. Fish. News. Int. 4(3): 283.
- Roels, O.A.**, 1969. History and present trends in fish protein concentrate production. U.N. Ind. Dev. Org. Exp. Group Meet, Agadir, Morocco, 14-18 Dec. 1969: 30-35.
- Skrede, A.**, 1983. Ensilert selavfall som for til mink (Seal offal silage as feed for mink). Norsk Pelsdyrblad 57: 399-407 (In Norw).
- Skrede, A.**, 1986. Forsök med konsentrert fiskeensilasje til rev og mink (Feeding trials with fish silage concentrate for fox and mink). (Norw). Norw. Agric. Coll. Manus. 12 p.
- Söbstad, G.**, 1987. Basic principles and technology of production of silage from fish. Proc. Fish Meal, Oil and Silage Conference, the Maritime Institute, St. John's, Newfoundland. April 22-23, 1987.
- Stone, F.E., R.W. Hardy and J. Spinelli**, 1984. Autolysis of Phytic acid and protein in canola meal (*Brassica* spp.), wheat bran (*Triticum* spp.) and fish silage blends. J. Sci. Food Agric. 35: 513-519.
- Stone, F.E. and R.W. Hardy**, 1986. Nutritional value of acid stabilized silage and liquefied fish protein. J. Sci. Food Agric. 37: 797-803.
- Stormo, B.**, 1983. Utnyttelse av selkjött/selavfall (Utilization of seal meat/seal offal). Inst. Fish. Tech. Res., Tromsø, Norw. Rep. No. 663.2-4-4. 68 p. (In Norw)
- Strasidine, G.A. and Y. Jones**, 1983. Ensiling dogfish (*Squalus acanthias*) processing wastes for animal feed. B.C. Research, Vancouver, B.C. Tech. Rep. 10: 1-22.
- Ström, T. and B.O. Eggum**, 1981. Nutritional value of fish viscera silage. J. Sci. Food Agric. 32: 115-120.

- Tarr, H.L.A., J. Biely and B.E. March, 1953.** The nutritive value of fish meal and condensed fish solubles, VII. Herring autolysates, fermentation products, condensed solubles and meal as supplements for chick starting rations. Fish. Res. Bd. Canada, Prog. Rept. Pac. Coast Sta. No. 94: 27-29.
- Tidemann, E., J. Raa, B. Stormo and O. Torrisen, N.A.** Processing and utilization of shrimp waste. N.A.: 583-594.
- Tatterson, I.N., 1976.** The preparation and storage of fish silage. Proc. Torry Res. station symposium on Fish Silage, Aberdeen. 16 p.
- Tatterson, I.N. and M.L. Windsor, 1974.** Fish Silage. J. Sci. Fd. Agric. 25: 369-379.
- Torrissen, O.E. Tidemann, F. Hansen and J. Raa, 1981.** Ensiling in acid - a method to stabilize astaxanthin in shrimp processing by-products and improve uptake of this pigment by rainbow trout (*Salmo gairdneri*). Aquaculture, 26: 77-83.
- Utvik, A. and P. Hansen, 1987.** Current developments in fish meal. Proc. Fish Meal, Oil and Silage Conference, The Marine Institute, St. John's, Nfld., April 22-23, 1987.
- VanKlaveren, F.W. and R. Legendre, 1965.** Salted cod. In: Fish as Food. Ed. G. Borgström, Academic Press 3: 133.
- VanWyck, H.J., C. Heydenrych, C. Williams, D. Garry and S. Milkovitch, 1983.** Naturally fermented fish silage II. FIRI, Cape Town. 37th Annual Report: 41-47.
- Viken, N.I. and F. Bjørge, 1987.** Silage Processing Plants. Proc. Fish Silage Workshop, Univ. St. Anne, Church Point, N.S., June 17, 1987. Fish. Dev. Branch, Dept. Fish and Oceans, Halifax, N.S.
- Ward, W.J., G.A. Parrott and D.G. Iredale, 1985.** Fish waste as silage for use as an animal feed supplement. Can. Ind. Rep. Fish Aquat. Sci., 158: iv + 10 p.
- Winter, K.A. and A.H. Javed, 1978.** Fish silage as a protein source for livestock and poultry. Agriculture Canada, Canadex livestock 400.64: 2 p.
- Woller, J., N.A.** Histamine in mink feed. Dansk Pelsdyravl N.A.: 26-29. (In Danish) (Reprint Available).

SILAGE PROCESSING PLANTS

Nils Ivar Viken, Vice-President
and Fredrik Bjørge, Manager, Engineering
Senta A/S
P.O. Box 133,
N-2301
Hamar
Norway

I. INTRODUCTION

A. Summary

The lecture describes the equipment and the processes for the production of silage which Senta A/S has developed alone, or in co-operation with research institutes or other companies.

The equipment is described technically, including valuable experience which Senta A/S has gained over a period of 8 years in the silage trade.

The importance of the plants being all automatic with current automatic control of the product in order to avoid human errors is highlighted.

The quality of the raw material is of utmost importance for achieving a good quality of the silage, and it is thus essential to preserve the raw material soonest possible.

The ensiling process is simple, however, it is important to have the right equipment, a good control of the raw material, and the right homogeneous admixture of acid, so that unpreserved lots are not entering the storage tank.

The protein concentrate gives a better feed and a lower consumption of binder meal, so that the feed on a whole will be cheaper. Fat can be separated during the concentrate production, allowing for the use of the feed for other species of animals than fish. According to requirements, fat can be added by individual consumer groups.

Senta A/S masters the various technical processes within the fish industry and tailors individual systematic solutions dependent on prevailing conditions.

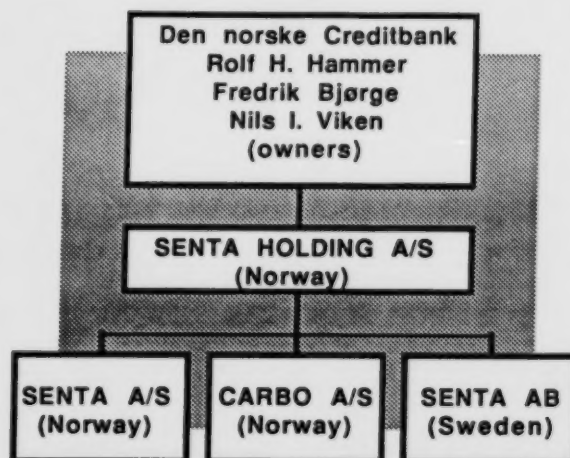
THE SENTA GROUP - A BRIEF PRESENTATION

The Senta group is marketing processes and equipment for the production of feed based on industrial fish and fish offal, and combustion plants for the production of energy.

The group holds patents and rights which form the basis of advanced and competitive deliveries.

The group is co-operating closely with research environments, and is based upon the extensive use of sub-supplies, and is, by so doing, able to market optimum solutions both technically and economically.

The organizational structure of the SENTA group is as follows:



SENTA HOLDING A/S

Senta Holding A/S is the owner and a developing company which holds the patents and rights that the subsidiary companies have at their disposal. Senta Holding A/S is selling license rights for its patented systems.

SENTA A/S

Senta A/S delivers machines and plants for the production of feed based on industrial fish and fish offal.

The company has a high level of competence within the processing technology and is capable of designing and delivering complete manufacturing plants.

CARBO A/S

Carbo A/S delivers complete combustion plants for all types of solid fuel from household waste to coal. The combustion system is patented and allows for choosing the fuel that gives the best economy at any time. The plants are delivered as turn-key systems of sizes up to 50 MW.

SENTA AB

Senta AB is marketing the services of Senta A/S and Carbo A/S on the Swedish market.

THE SERVICES OF THE SENTA GROUP

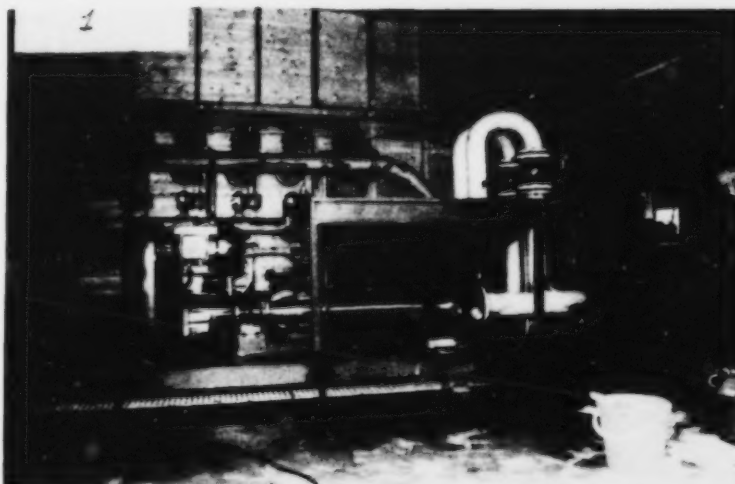
1. Prefabricated fully automatic ensiling plants for industrial fish and fish offal.
2. Turn-key manufacturing plants for the production of protein concentrate based on silage.
3. Turn-key manufacturing plants for the production of protein concentrate based on fermented silage. ENSIFERM®.
4. Delivery of culture of bacteria for fermentation.

5. Turn-key manufacturing plants for the production of fishmeal based on low temperature process.

6. Turn-key combustion plants, flexible plants that are able to use all types of solid fuel without any technical readjustment.

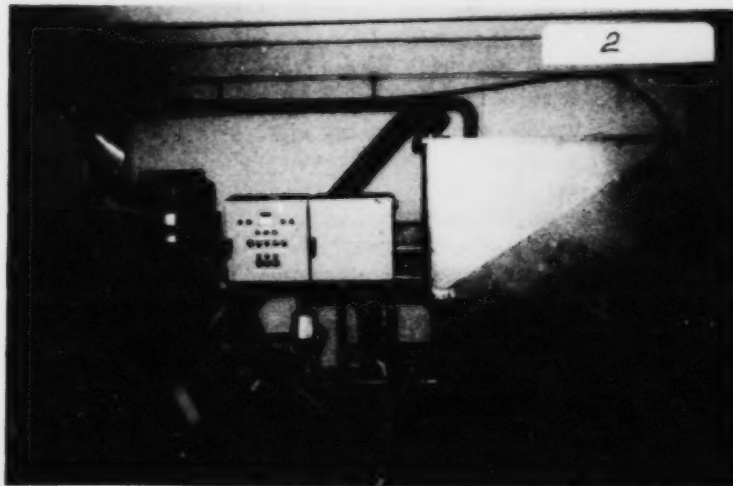
7. Technical consulting within processing technique, energy saving measures, technical/economical analysis of projects.

8. Guarantees concerning capacity and function.



Photograph 1

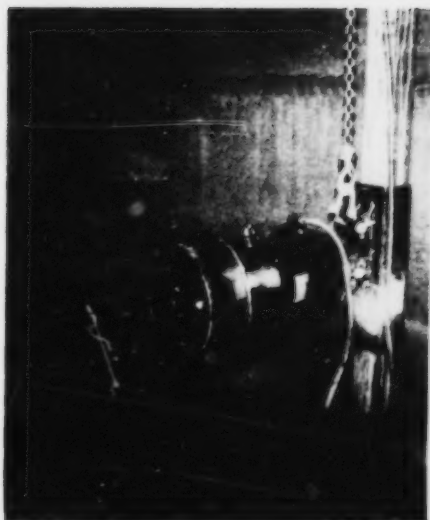
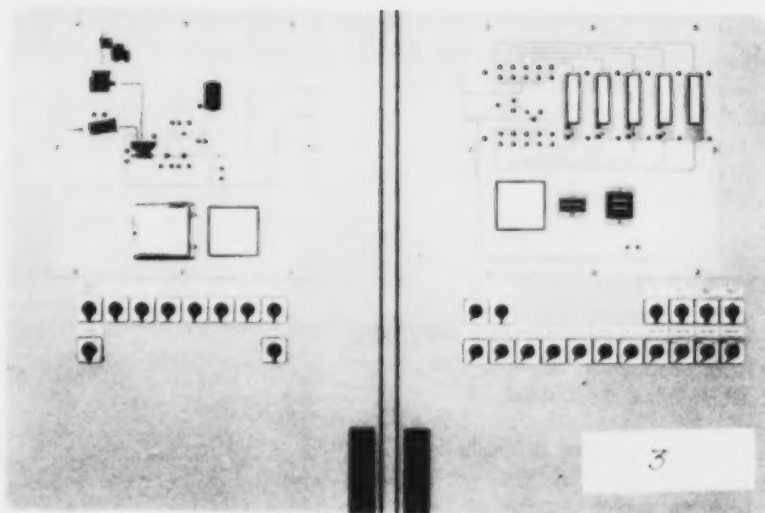
Ensiling plant for all types of fish and fish offal, 4-8 tons per hour. All automatic operation. pH control.



Photograph 2

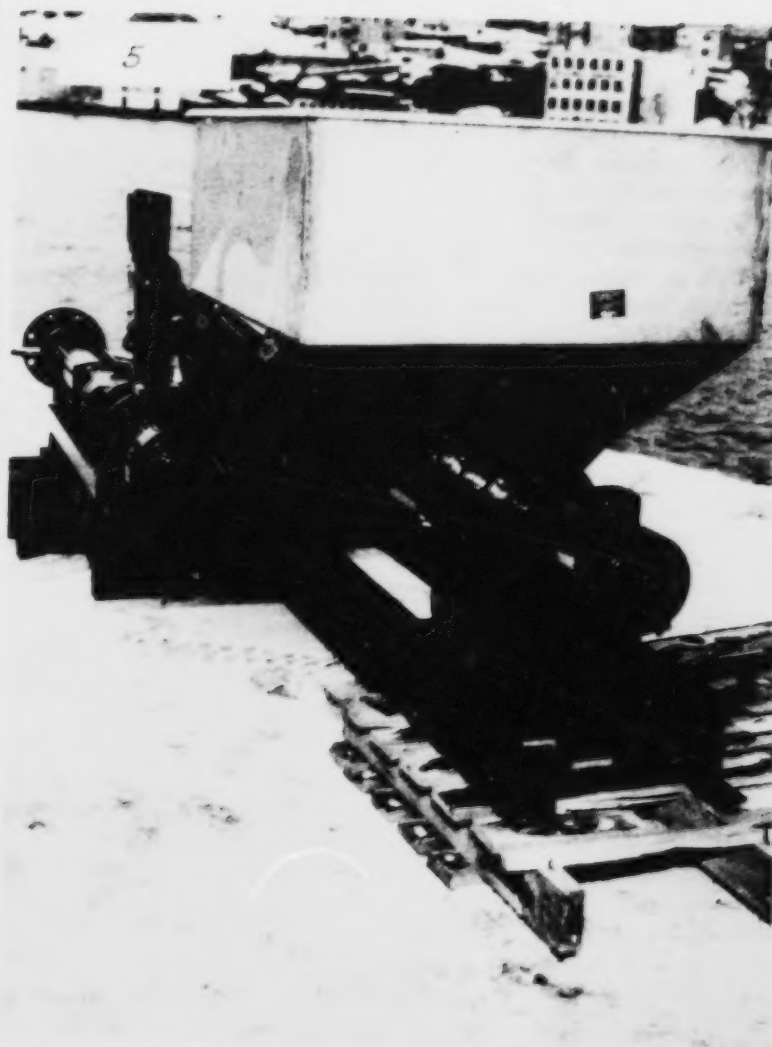
Ensiling plant for all types of fish and fish offal, 25-35 tonnes per hour. All automatic operation. pH control.

Photograph 3
Control panel for SENTA
ensiling plant with pH
monitor (right).
Monitor for tank plant,
volume, pH, and valve
guides (left).



Photograph 4
Stirring mechanism
mounted in ensiling tank.
The stirring mechanism
can be turned in all
directions and can be
hoisted up for service
and maintenance.

Photograph 5
SENTA 6000 with device
for receiving fish offal.
Mounted, test run, ready
for delivery.



B. Fish Silage

The product of the process of preserving and storing wet fodder in a silo is called a silage. The traditional use of the word has been in conjunction with green forage, preserved either by added acid or by the anaerobic production of lactic acid by bacteria. The ensiling of fish has been adapted for analogous products of whole fish or part of fish.

C. Production Principles

There are two methods for production of fish silage:

1. By adding acid, inorganic and/or organic (=acid-preserved silage), which lowers the pH sufficiently to prevent microbial spoilage.
2. By bacterial fermentation (=fermented silage), initiated by mixing the fish with a fermentable sugar which favours growth of lactic acid bacteria. These bacteria may be naturally present in the fish. It is advisable, however, to add the bacteria as a starter culture. The lactic acid bacteria produce acid and antibiotics which together destroy competing spoilage bacteria.

Ensiling by adding acid is the method most commonly used. This method gives a reliable and easy preservation. Fermented silage has a better taste and a better digestibility than acid-preserved silage, however, the process has to be regarded as far more complicated than is the case of acid-preserved silage.

There are two methods for the further processing of silage:

1. Acid-preserved silage is heated to about 90° Celcius, oil is separated, and the protein water is evaporated to 45-50% DS.
2. Senta A/S has in co-operation with Biotec A/S developed a refining process for fermented silage. The processed produce is called ENSIFERM® and is in broad outline identical to the process mentioned under item 1.

In the case of great distances between the producer and the consumer of silage, the further processing of silage is most advantageous as the volume to be transported is reduced by about 60 per cent. In addition, the requirement for binder meal to be added to produce the correct feed mixture is reduced.

Only in the case of great quantities, 10,000 metric tons and above, will further processing of silage be of current interest.

II. POTENTIAL RESOURCES FOR SILAGE

A. By-Catch on Trawlers

Trawlers continually catch types of fish that are not utilized and which are normally scrapped on the fishing grounds. However, used as feed, this resource contains a nutritional value equal to that of any other fish.

B. Offal from Fish Processing

Commercial industrial processing of fish for human consumption yields about 40% edible flesh and 60% by-products.

C. Periodic Surplus of Fish

Fish may be caught periodically in quantities exceeding the local processing or freezing capacities. This occurs both in industrialized as well as in developing countries. Preserving and storage as a silage seems to be the most convenient way of salvaging these resources.

III. POTENTIAL MARKETS FOR SILAGE

Chemical analyses and practical feeding tests show that fish protein-based feeds are high-quality products which can be fed to all ordinary domestic animals, fur-bearing animals, and fish.

The commercial use of silage must involve control of the oil content. Used as feeds for domestic animals it is most important that the oil content is low as marine oils in great quantities may add a fishy taint to the product. Two to three weeks in advance of the slaughtering, a change of the diet is recommended.

In Norway the silage is used first and foremost by the fur-bearing animal industry as well as the fish farming industry. About 15 per cent of silage is mixed into the feeds for the fur-bearing animals; any greater percentage of admixture would entail that the pH of the feed would be too low.

The percentage of admixture can be radically increased in the feeds used in the fish-farming industry, the restriction being most often the consistency wanted of the ready feeds as it is desirable to produce pellets for use in the automatic feeding plants. Silage with an oil content of about 16 per cent is mixed with 50 to 60 per cent binder meal.

IV. TECHNOLOGY OF SILAGE PRODUCTION

An essential condition to achieve a successful result in the case of acid preservation, is based on the raw material being fresh. In the case of an incipient decomposition of parts of the raw material, this process is not going to cease by the ensiling of it. Insufficient admixture of acid will also entail that the decomposition starts. Such conditions might entail that the remainder of the silage will be contaminated with the result that a whole lot (storage tank) can be destroyed.

However, it must be pointed out that the silage may have a certain buffer effect owing to the fact that the bone substance of the fish contains calcium.

The main conditions for achieving a good result, I want to summarize as follows:

- fresh raw material
- good grinding of all raw material
- the admixture of the right amount of acid
- homogeneous admixture of acid.

When choosing the equipment, these conditions must be fulfilled. Furthermore the equipment must be dimensioned for the capacity and for the raw material which is of current interest. Also the plant has to be equipped with automatic control and a safety system that will reduce the possibilities of making errors.

This is a prefabricated automatic plant which can deal with all kinds of offal and whole fish.

The offal is here fed by means of a conveyor belt through to the feeding hopper. Level electrodes which automatically stop and start the plant are mounted in the feeding hopper. At the bottom of the feeding hopper there is a conveyor screw that ensures

Figure 1 shows SENTA's solution in principle (SENTA 6000).

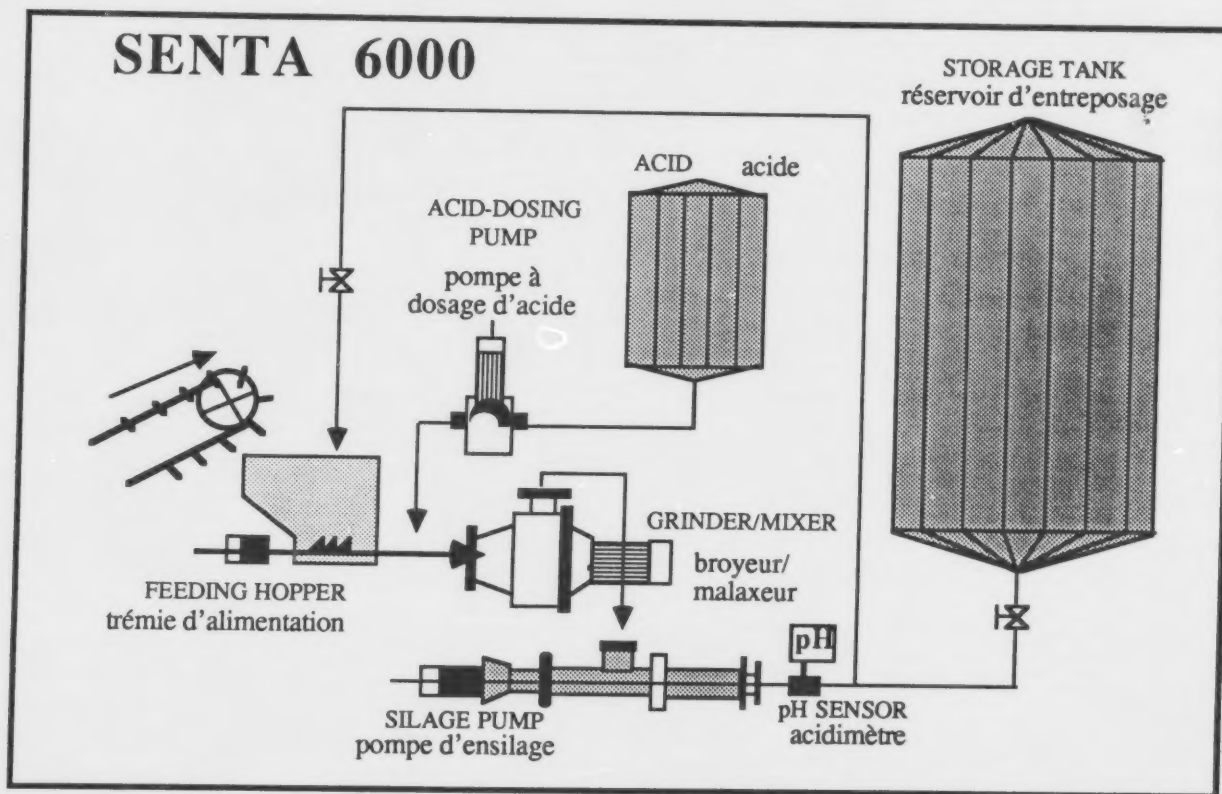
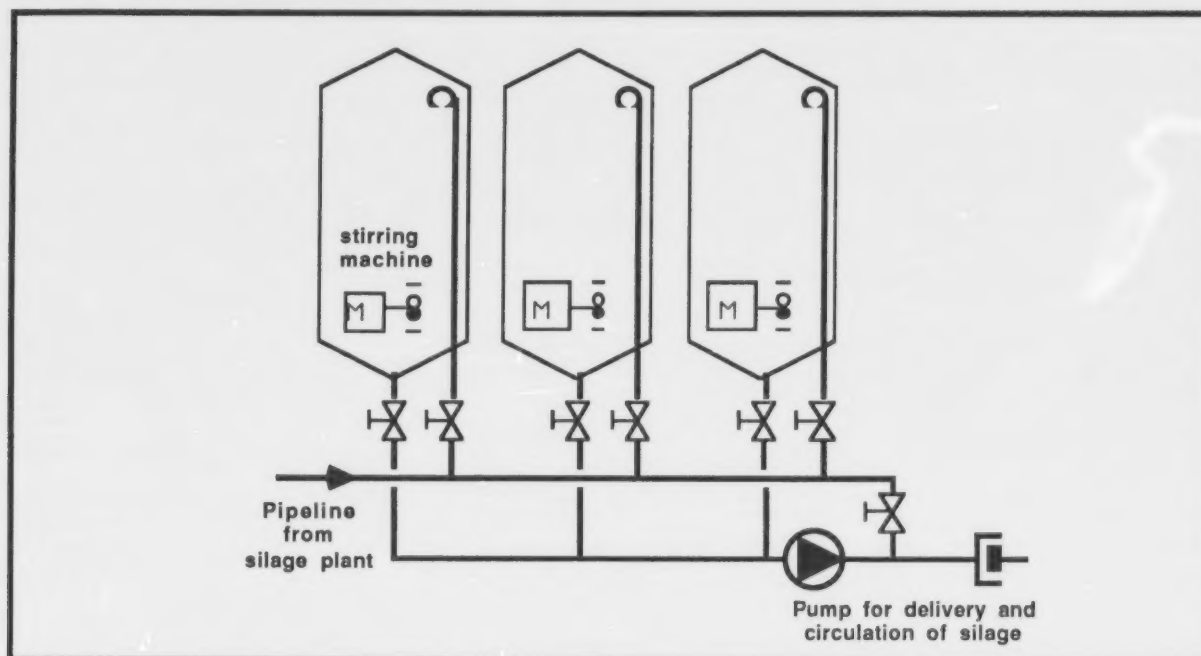


Figure 2 shows the arrangement of a tank plant.



a stable feeding of the offal into the plant. The conveyor screw is designed in such a way that it will prevent the rise of bridges in the feeding hopper.

The mill is directly coupled to the feeding hopper. Preserving acid is added at the entrance of the mill. The mill is a fast-speed knife mill which, besides grinding the offal, also performs the homogeneous admixture of acid.

The dosage unit consists of a metering pump with adjustable capacity, tank for acid, and necessary fittings (solenoid valve, pressure controlling valve, filter, etc.). The acid tank has a level switch which warns before the tank is empty.

The product pump is placed immediately after the mill. It is the product pump which decides the capacity of the plant. The pump yields a stable quantity per revolution/time unit. Thus we have a synchronous relation between the capacity of the product pump and the acid dosage pump.

The silage is thus pulled through the mill and is pumped into the storage tanks. A pH-feeler which registers the pH-value of the silage is mounted at the outlet of the product pump. The signal from this is transmitted to an instrument which is mounted in the switch board. On the instrument it is possible to set the limits required concerning the highest and lowest permitted pH-value. Whenever deviations from the

limits set are registered, the plant is automatically stopped, and signal is given so that an operator is summoned.

Most often the plant is equipped with a return pipe to the feeding hopper so that the silage can be re-circulated. This is used when the plant is put into operation to secure that the right pH-value is established before the plant is run automatically.

The return pipe is also used when the ensiling is terminated. When the feeding hopper is emptied, there will be unpreserved product at the bottom and in the outlet from the feeding hopper. Through re-circulating the silage, also this remainder will be preserved. The procedure eliminates the daily need for wash.

A plant of about 6000 kg per hour has an installed electric power of about 35 kW.

Silage from the ensiling plant is pumped directly into the storage tank. The silage is normally pumped into the tank at the top and is depleted from the bottom of the tank. In connection with the tank plant, a pump is installed which is used for: 1. emptying of tanks, 2. re-circulation of silage, 3. pumping of silage from tank to tank.

A silage gradually liquefies due to the activity of tissue

degrading enzymes which are naturally present in the fish, mainly in the digestive organs. The rate of this liquefaction or autolysis is determined by the activity of digestive enzymes in the raw material, the pH, the temperature, and by the preservative acid.

The moment the silage is produced, it has a very solid consistency. In the storage tank, the autolysis will, dependent on the factors mentioned, entail a liquefaction of the silage. These circumstances will entail that the silage is separated into three phases in the tank. Bone substance and mud will gather at the bottom. In the middle layer we find the protein water, and the oil is separated at the top. It is thus necessary to arrange for a good stirring of the silage so that the three phases are kept in a homogeneous mixture.

On small tanks, until 50 m³, the pump of the tank plant will normally succeed in carrying out this task. The condition is that the pump has an hourly capacity of about 0,75 - 1 times the volume of the tank.

Anyhow, a stirring mechanism/mixer is to be preferred as concerns the stirring, as the effective output exceeds many times over the output provided by pump circulation. In addition the silage is to a much greater extent exposed to the surrounding air when being circulated by a pump as the silage is then pumped out and above the fluid level in the tank. The exposure to the air entails oxidation of the oil which turns rancid.

The tanks should be provided with automatic level controls notifying at full or empty tank as well as an instrument indicating the quantity of silage contained in the tank.

The stirring mechanism/mixer should be arranged as shown in the following diagram. It can be hoisted up and down and can be angled at all levels.

Pumping of Silage

Throughout all stages, the silage will be a product that can be pumped. The moment the preserving acid is added, the fish product gets a very solid consistency due to a biochemical reaction. Heterogeneous raw material will cause variations of the consistency. Hence it is of utmost importance that the pipelines and pumps are dimensioned with a sufficient capacity.

Positive-displacement pumps are always used for silage. We consequently use the eccentric-screw type pumps. These can be supplied with pressure stages of 6-12-18-27 Bar O. The pipelines are dimensioned in such a way that one-stage pumps (max. 6 Bar O) will

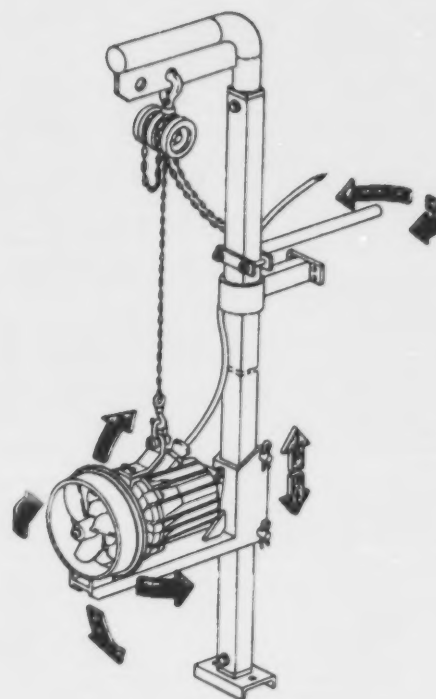


Figure 3 shows an arrangement of stirring mechanism/mixer.

normally be sufficient.

By way of example:

An ensiling plant with a capacity of 10 cubic metres per hour and a product pump with a rating of 6 Bar O will manage to pump the silage in a pipeline of diameter 150 mm to the storage tanks. The actual length must not exceed 40 metres.

Silage that has been stored will take on a lower viscosity, and thus the dimensioning of the pipes and the pressure-capacity of the pump in connection with the tank plant can be dimensioned with a considerably lower coefficient of friction.

Long pipelines at the suction side of the pump should always be avoided as cavitation will easily arise in the pump, especially if the change of consistency through autolysis is insignificant. Cavitation will cause considerable vibrations in the pipelines.

Choice of Material in Processing Plant, Tanks, Pipelines and Fittings

The preserving acid is an aggressive fluid and thus acid-proof material has to be used in connection with this. Non-corrosive steel of quality AISI 316 is normally used, however, various plastic materials (PVC, PEH) can also be used.

No special demands are made on the choice of material concerning that part of the processing plant that does not get into contact with concentrated preserving acid, and the same holds good for pipelines, tanks and fittings. The silage is not aggressive in spite of the fact that concentrated acid has been added to it. The admixture of acid totals about 2,0 - 2,5 per cent, homogeneously mixed with the fish product. The fat present in the silage will act as an insulating layer against corrosion.

However, the attention should be drawn especially to one circumstance concerning silage and choice of material. Galvanized surfaces of the steel construction which get into contact with the silage will cause galvanic corrosion developing explosive gases (oxyhydrogen gas compounds).

Dosage of Preserving Acid. Development of pH.

One detail is of special importance when ensiling, and that is the right dosage of the preserving acid. In addition to having to grind the raw material into such a consistency that the acid will enter sufficiently into the material, the dispersion of the acid has to be completely homogeneous.

We consider silage with a pH lower than 4,5 to be stable for storing. In practice we use pH 4,1 - 4,3.

If the pH-value is measured immediately after the acid is added it should be much lower than pH 4,1 - 4,3, how low it should be depends on the raw material, but we would suggest about 3,6 - 3,8.

The moment acid is added, the readings of the pH-value will be artificially low due to the fact that the acid within a short enters the cell structure. Furthermore, the bone substance will cause buffering (neutralizing) of the acid. Thus the greater the quantity of bone is, the lower the starting pH-value should be.

Figure 4 shows a typical development of pH in fish offal.

It is important that the pH-value of the silage is

controlled. In case the pH-value develops in such a way that the limit of pH 4,5 is reached and even exceeded, it is possible to re-adjust by adding more acid. If the silage has developed in such a way that it has a rotten smell, it is too late for compensating by re-adjusting the pH-value.

Formic acid is used as a preserving acid.

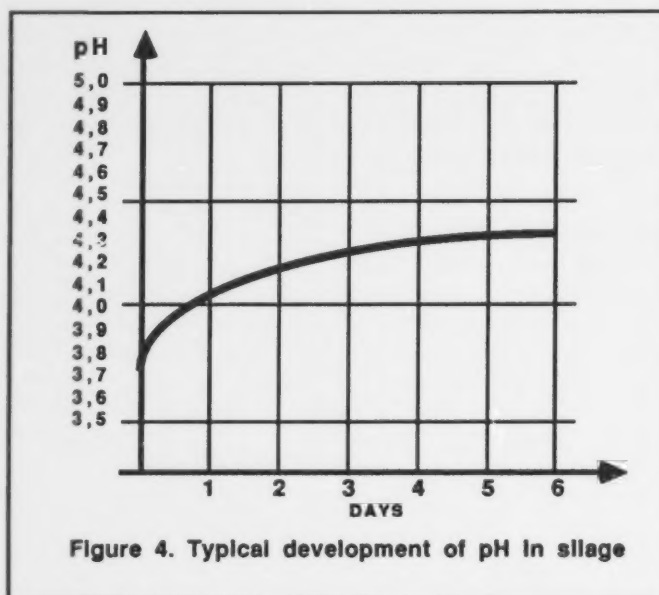


Figure 4. Typical development of pH in silage

Oxidation of Fish Oil

Unsaturated fatty acids in lipids react with oxygen and form hydroperoxides as the initial products. The rate of formation of hydroperoxides decreases as the more reactive fatty acids become oxidized, whereas the rate of breakdown is accelerated as the hydroperoxide level increases.

Consequently, the level of lipid hydroperoxides in foods or feeds attains a maximum during storage. This maximum may be reached in a few days or months, depending on many factors, including temperature of storage, available oxygen, the presence of pro- and antioxidants and reactivity of the lipids.

The concentration of hydroperoxides in oil (fat) is usually determined by the iodometric method and the peroxide value is expressed as milliequivalents of peroxide per kilogram fat.

The peroxide value is a useful analytic figure, since oxidized fat in animal and fish rations cause loss of appetite and decreasing ability to gain weight.

The typical off-flavours (rancidity) of oxidized fat are attributed to volatile carbonyls formed during decomposition of hydroperoxides.

To prevent or reduce the formation of peroxides in the oil we have to mix an antioxidant into the silage. In Norway ethoxyquin is normally used, and it can be mixed into the preserving acid (formic acid) and will thus be dosed homogeneously and correctly into the silage. This type of antioxidant is mixed with about 150-200 ppm, which means about 7,5 - 10 kg per ton of formic acid.

V. POSSIBLE ORGANIZATIONAL MODEL FOR ENSILING AND REFINING OF SILAGE

The described model is based on supply of raw material from local silage making facilities, either on board trawlers or at the fish processing industry on shore.

It is important to establish suitable distribution channels for the sale of the products. The choice of model will

therefore depend upon the potential markets and the local conditions.

Figure 5 shows a model involving a central refining processing plant where the final product is protein concentrate and fat.

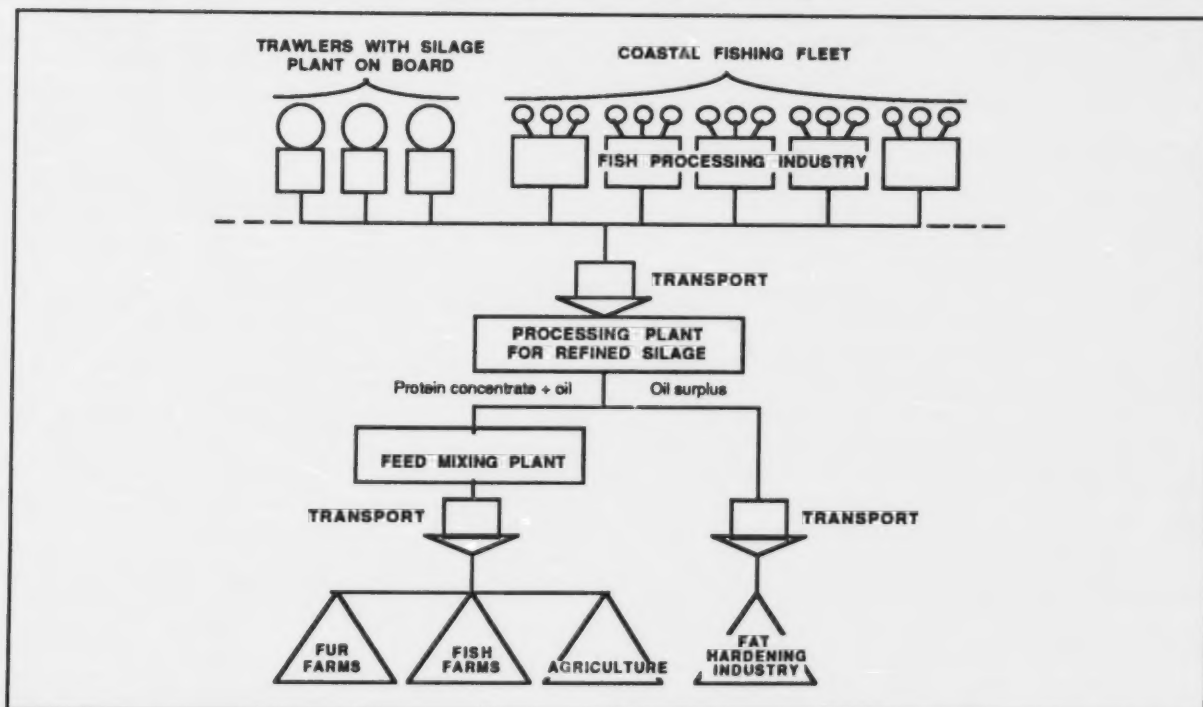
This model is based mainly on production of evaporated silage. In its concentrated form, evaporated silage is highly suitable for admixture with binder meal.

Concentrated silage is also cheaper to transport due to the fact that the volume has been reduced by 2/3.

Concentrated silage also has several advantages in better nutritional value. Furthermore, the fact that we can reduce the amount of binder meal compared with ordinary silage results in a better economy.

Our statements concerning better economy are only valid provided the raw material basis is sufficiently large (from about 10-15,000 tons per year) and that other local conditions are satisfactory.

Figure 5. Organization Model for ensiling and refining of silage.



VI. SENTA A/S AS A SUPPLIER OF SILAGE AND REFINING PROCESSING PLANTS

Senta undertakes the complete planning of optimum technical and economic projects for the processing of fish offal.

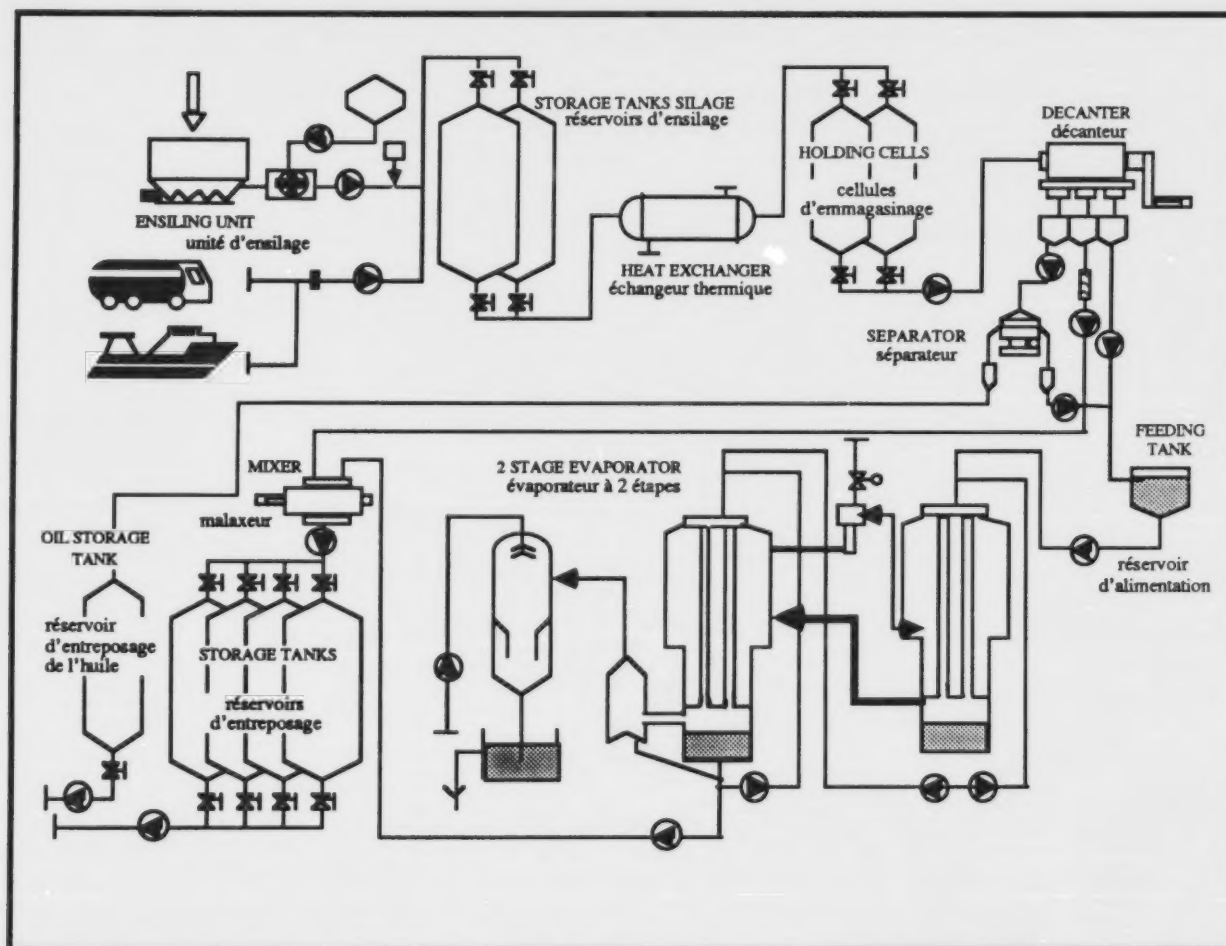
Our engagement includes the whole processing complex from raw offal to finished product.

Senta co-operates with the well-reputed firm Hetland Process, Division of Myrens Verksted A/S concerning evaporation and heat treatment in refining processing plants. Hetland Process, Division of Myrens Verksted A/S is one of the greatest and best firms of recognized standing concerning building of factories within production of fish meal, and with world-wide references.◊

Literature cited and other references:

1. J. Raa, A. Gildberg, Fish Silage: a review. Institute of Fisheries, University of Tromsø, Norway.
2. K.E. Andersen, personal discussions. Biotec A/S, Tromsø, Norway.

Fig. 6 shows SENTA's solution for concentrated silage.



PROCESSING AND APPLICATION OF CONCENTRATED FISH SILAGE AS FEED FOR FISH, MINK, FOX AND POULTRY

Ole Peter Ulvestad
Managing Director
Royal Seafood A/S
Olav Tryggvasongt 40
N-7000 Trondheim, Norway

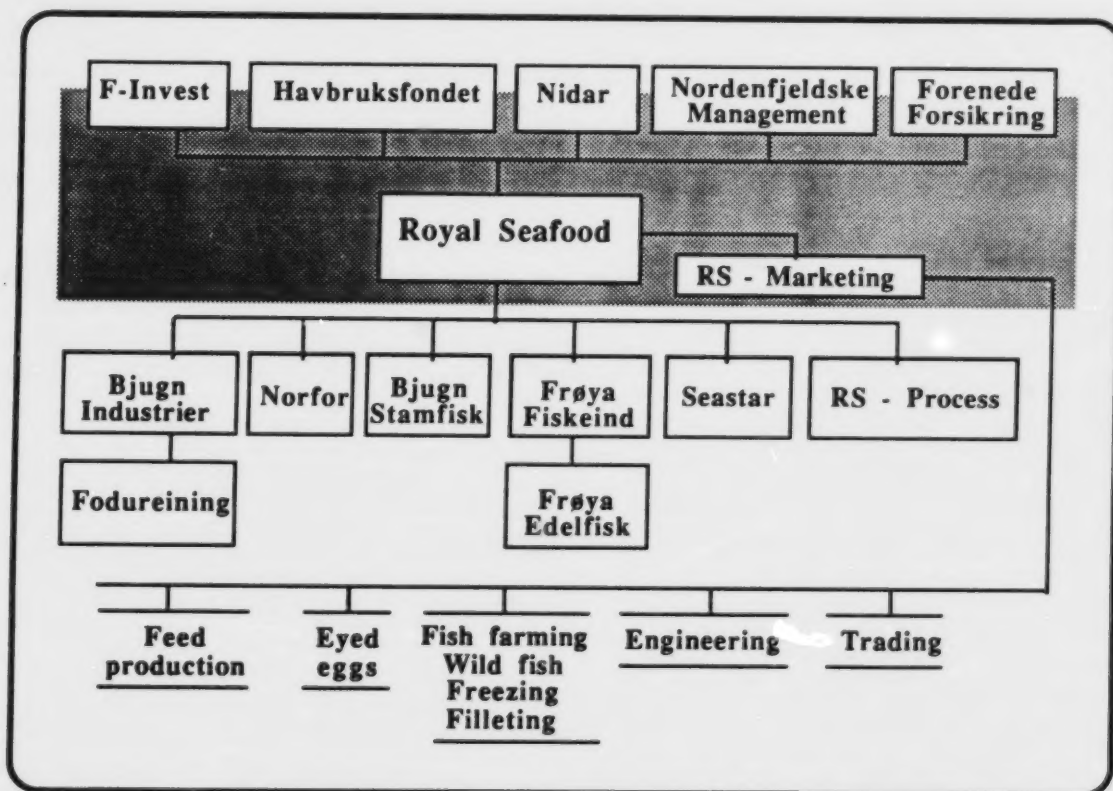
Royal Seafood A/S is located in Trondheim, Norway and is a private company owned by a strong capital group involved in: banking, insurance, a food and nutrition company, one private investor and an aqua investment fund.

Royal Seafood is the holding company for a group of companies covering most activities within fish farming. We produce eyed eggs, fish feed and fish feeding systems. We are also involved in fish farming with an

annual production of 300-400 tons of salmon. In the salmon trade (fresh and processed), we process wild fish and do filleting, freezing and smoking.

Our engineering company covers the processing part of fish farming, but is also actively involved in process concepts for fish meal and oil and in dairy and food engineering.

Figure 1. Royal Seafood Companies



Our companies are:

R.S. Process A/S:

Engineering for fish farming:

- Equipment for the production of fish silage
- Evaporators, pasteurizers etc. for fish silage
- Automation
- Complete feed plants and feed kitchens
- Fish feeding systems

Fish meal industry:

- Waste heat cookers
- Waste heat evaporators
- Enzymatic treatment

Fish liver oil:

- Crude oil plants
- Refining of oils

Process engineering within the fruit juice industry, utilization of slaughterhouse wastes etc.

Bjugn Industrier A/S:

- Fish feed production
- Mink and fox feed
- Testing of feed recipes
- Research and development of new process concepts

Bjugn has subsidiary fish feed companies in Norway and Iceland.

Bjugn Stamfisk A/S:

- Production of salmon eyed eggs

Frøya Fiskeindustri A/S:

- Salmon farming
- Processing of wild fish
- Filleting and freezing plant
- Smoking plant

Seastar Resource Corp., B.C. Canada:

This company is owned 25% by Royal Seafood.

- Fish farming
- Fish feed plant presently under construction

- Smoking, filleting, freezing
- Trading

Royal Seafood has the intention to market all the expertise and know-how covered by these companies on an international market. We are also interested to participate in industry projects.

We offer:

- Complete fish feed plants based on fish silage
- Fish feeding systems
- Know-how covering a wide range of fish farming
- Training of personnel at our installations.

Fish feed:

In Norway, the fish feeds have undergone a continuous development process.

Most farmers started by producing their own feed ... and still many do, but more and more get their feeds from feed manufacturers either as dry pellets or as a moist pellet or paste.

The feed produced at the farms was mostly based on frozen capelin.

The raw material has to be thawed and when fed, a lot of the water part of the feed dissolved in the sea water. This gave a large feed loss and caused serious water pollution.

Dry feed:

The dry feeds have been developed into high quality products and are today available for fish weighing from 0,2 grams upwards.

The pellets are produced in sizes from 0,3 mm up to 10 mm.

The fat content ranges between 14,5 to 23%, protein between 38 and 53%, carbohydrates between 15 and 30% and ash between 6,5 and 8%.

The total dry matter content is approximately 90%.

A typical high quality dry pellet has the following composition:

Fish meal (high quality)	: 63%
Wheat (extruded)	: 20%
Fish oil	: 15%
Vitamins, minerals, binder	: 2%

A more standard quality has this composition:

Fish meal	: 32,0%
Soya meal	: 27,5%
Wheat	: 26,5%
Fish oil	: 11,5%
Vitamins, minerals, binder	: 2,5%

There are a number of dry feed qualities on the market and the type to be used as optimum depends upon the type of fish, its size and the water temperature.

For high quality feeds, only the very best raw materials are to be used - the fish meal has to be produced from fresh and unconserved fish and the processing has to be carried out at low temperatures.

Furthermore, the carbohydrates have to be extruded. This makes the product rather expensive. At our test plant, we have found that the feed costs to produce one kg of salmon based on the high quality dry feed is approximately \$1,60 US. We found that the cost of feed based on concentrated silage was approximately \$1,10 US. These figures are based on feed and raw material prices in Norway.

Fish silage:

In our opinion, a moist feed is a better and more natural feed than a dry feed. Fish feed naturally on other marine species, on protein and on fat that have not been subjected to any heat and on fresh water.

With a dry feed, the fish must produce the fresh water. Especially when the water temperature is low, this process will be a strain on the fish and it is well known that some will stop the intake of feed.

With a moist feed, which contains fresh water, the fish takes the feed although at a somewhat reduced rate.

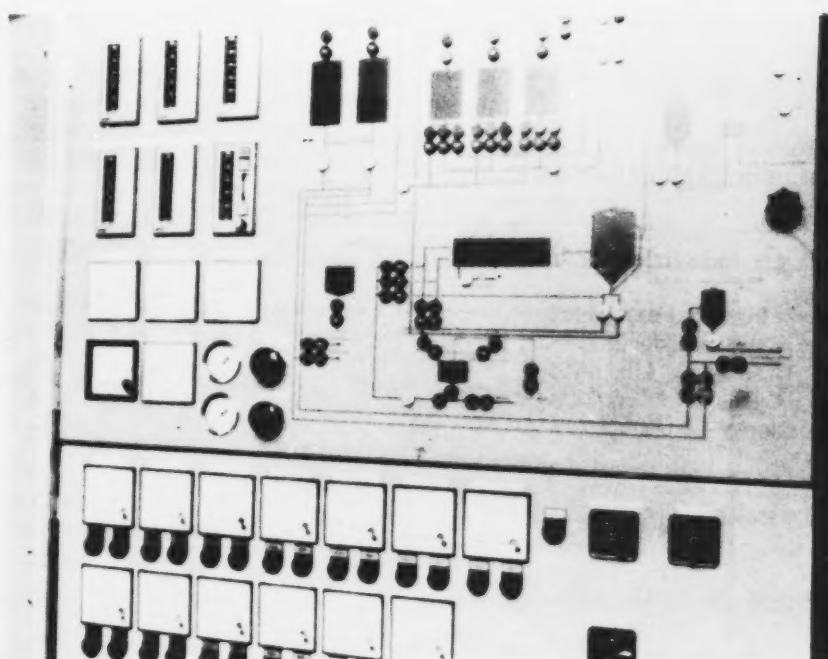
A minimum of heat is applied during the process and the proteins therefore do not get denaturated. A fish meal process is a far more tough process and tests have shown that the digestibility of the silage protein is superior to the best quality of fish meal.

The purpose of using fish silage in concentrated form is to reduce feed costs.

Fish silage has unfortunately had a rather poor reputation. The silage process has been regarded as a way to get rid of any type and quality of industrial fish and waste. The end product, of course, is no better than what is put into it and it is very important to set quality demands as to the raw material processed.

Only fresh fish raw material is therefore used, either processed on board the fishing vessel or else the waste is processed immediately as it comes from the filleting table.

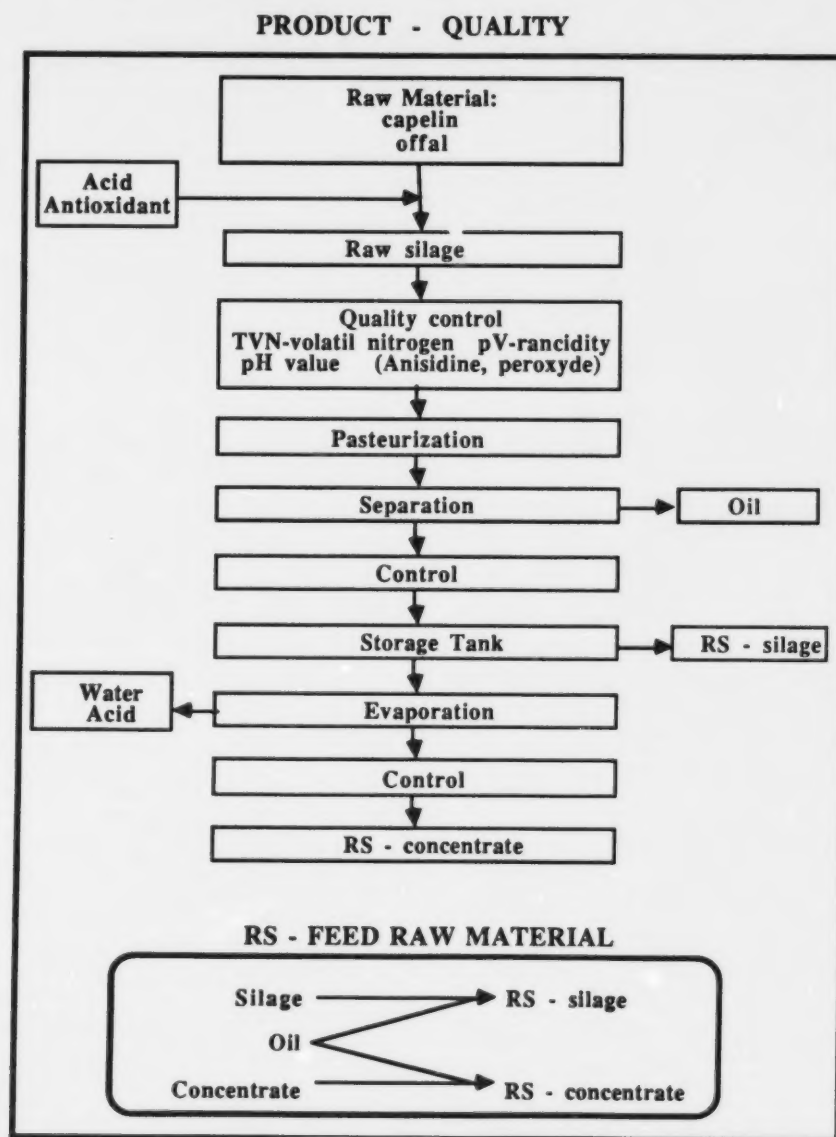
Figure 2. Control panel for concentration



The fish is ground and formic acid added to reduce the pH to around 4,0.

The bacteriological activity is thereby stopped, but the fish enzymes will break down the protein chains such that the fish takes on a liquid consistency. If the enzymatic action is not stopped after a certain time, the product might get a bitter taste and therefore cause the fish to loose their appetite.

Figure 3 Process steps for silage production



At a certain stage, the enzymatic action is therefore stopped by a short time pasteurization. To avoid oxidation of the fat an antioxidant is added.

After these process steps, the product is stable and can be stored for a long time without losing any quality. The process steps are shown in figure 3.

The fish is ground into a fine slurry, acidulated with formic acid and pumped into intermediate storage tanks. The fish slurry is then heated to around 30° and held in the Rotacell retention tank for about one hour.

During this time and at this temperature the required enzymatic action is achieved. The raw material is then pasteurized, the oil is separated and momentarily cooled in a vacuum flash cooler or passed directly into the low temperature evaporator.

The final concentration is around 50-55% TS and its consistency is like a paste. This paste is the main ingredient in our silage moist feed.

It is possible to use silage that is not concentrated. The feed then consists of approximately 50% silage, and

50% binder meal, vitamins etc. On a dry matter basis, the dry matter from the silage is only around 18%, the rest being part of the dry components.

When the concentrate is used, the silage part can range as high as 80% and the binder only 10-15%. When using concentrate, the dry matter from silage has been increased to as much as around 73% and the rest is part of the fish meal, etc.

The concentrate has a pH approximately of 4,5. Dried shrimp shells are used both to increase the pH to 5,2 and also to give the fish flesh the desired red colour. At our plant, we use only shrimp shells and avoid the artificial colour which we expect to be prohibited.

Figure 4. Analysis and use of RS-silage and RS-concentrate

ANALYSIS OF THE RS - SILAGE AND RS - CONCENTRATE					USE OF RS - SILAGE AND RS - CONCENTRATE IN FEED PRODUCTS	
Spec.weight kg/m3	DM %	P %	F %		50	50
RS-SILAGE 980	23	14	7		RS-SILAGE	MEAL ETC
RS-CONCENTRATE 1150	50	34	10		RS-PELLETS	
					60	40
					RS-SILAGE	MEAL ETC
					RS-PASTE	
					70	30
					RS-CONCENTRATE	MEAL ETC
					RS-PELLETS	
					80	20
					RS-CONCENTRATE	MEAL ETC
					RS-PASTE	

RS-SILAGE 20% DM	2,5 kg
↓	
RS-CONCENTRATE 50% DM	1,0 kg

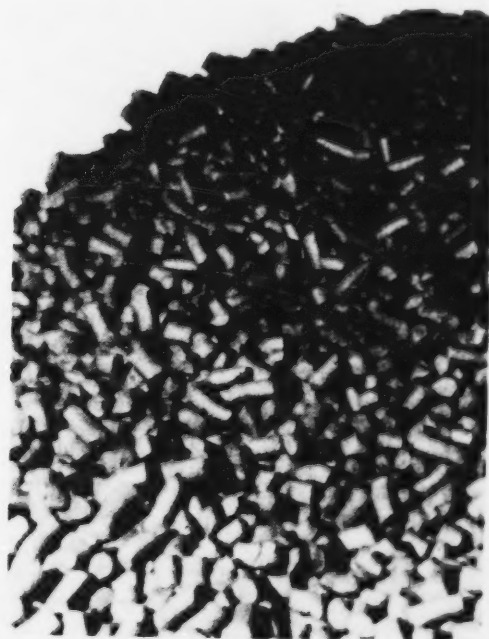


Figure 5. Silage pellets

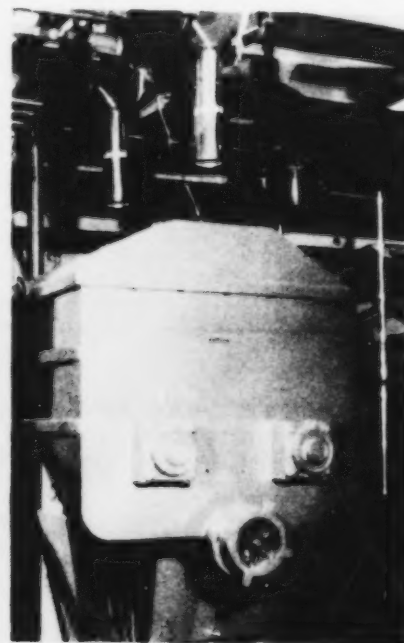


Figure 6. Mixer for pellets and paste

Silage is concentrated at low temperatures to avoid denaturation of the proteins. Prior to concentration, the product has been pasteurized, but the exposure time has been short and the protein quality has been maintained during this process. The evaporation process, on the other hand, requires a longer retention time, but the applied temperature does not rise above 50°C. At this temperature, the concentrate becomes somewhat viscous and the evaporator design is important. We apply the principle of forced circulation flash which involves that the product is pumped through the heat exchanger, heated and thereafter flashed into high vacuum where the water is evaporated by flashing. The design can be either a single effect with thermo compression or a straight double effect system.

The evaporation process is continuous with complete automation and also includes automation for the desired concentration. The system has a regeneration system of energy such that the preheating of the raw materials is done by cooling the pasteurized product after fat separation.

The total fuel oil consumption of this system depends of course on the analysis of the raw material, but as a general figure, we reckon an average 30 kgs of oil per ton of fish.

The total costs, including depreciation, labour, maintenance, etc. will have to be calculated for each project according to the expected operating hour per

year and total production.

All process equipment is designed in stainless steel due to the use of formic acid. Mild steel equipment can be used when the process temperature is below 25-30°C. The raw silage equipment is therefore designed in the cheaper material.

Cleaning of the equipment is no problem as both the low temperatures and small temperature differences used do not cause any burning on the heat surfaces. The sporadic cleaning is therefore usually performed with water only. As the pH is between 4,2 and 4,5 throughout the whole process, no reinfection of bacteria will occur.

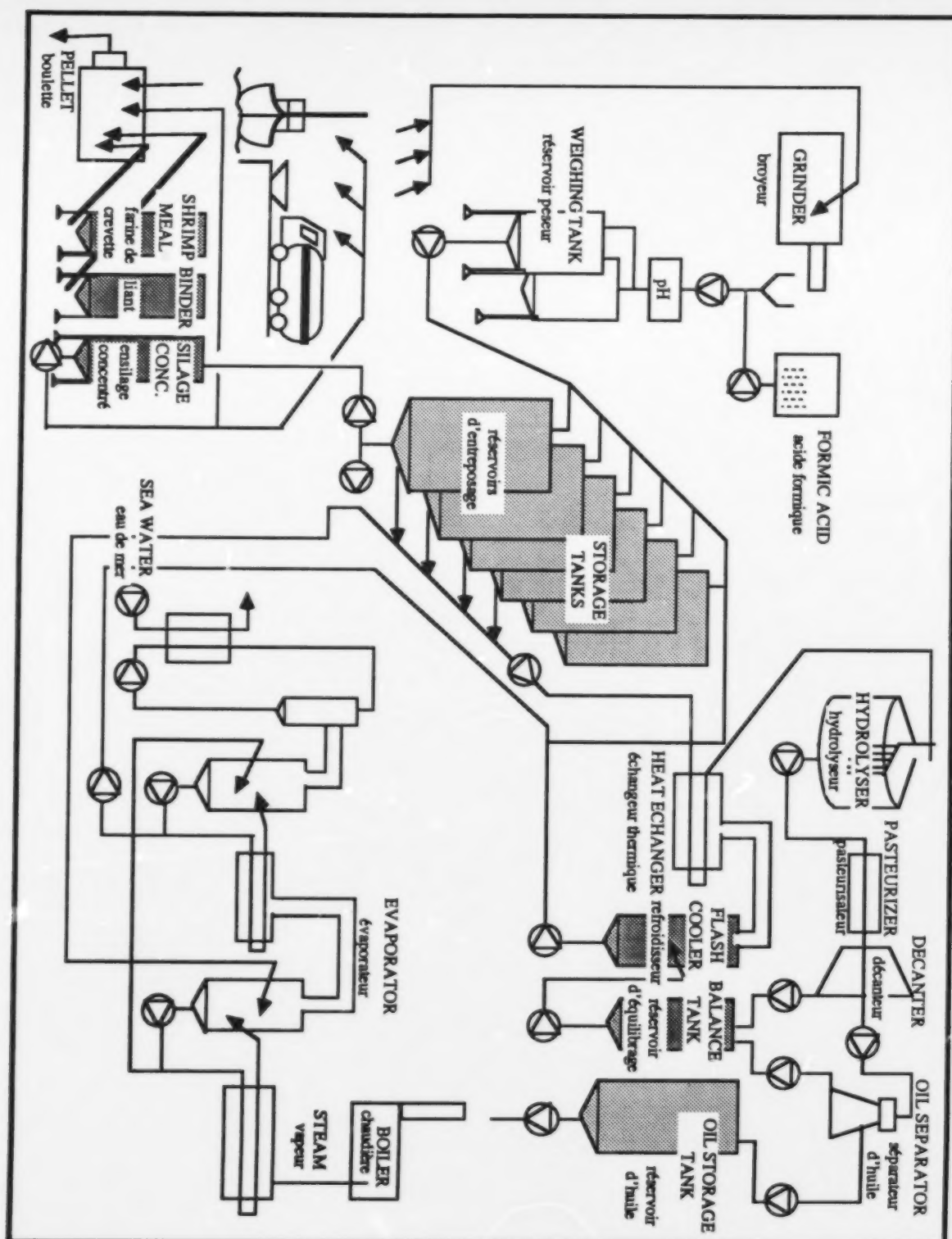
The process involved to produce the concentrated silage requires much less energy than the fish meal process and has much less equipment requirements. It is therefore obvious that by replacing a major part of the expensive fish meal, a cheaper feed can be obtained.

The ingredients required to produce the final feed are added by a program to the feed mixer. At our plant, five different recipes are programmed. The mixer is erected on load cells and a computer demands the amounts of silage concentrate, oil, shrimp meal and binder. The fish farmer is therefore assured that the composition of the feed meets his requirements. The feed is then made into pellets or paste and transported either in plastic containers or by a road tanker to the fish farm.



Figure 7. Truck transport

Figure 8. Schematic layout of silage plant



To avoid reinfection, especially in summer, the concentrate is cooled to 4 - 6°C before storage.

The silage process gives the proteins a very gentle temperature exposure.

The high temperature is only applied during pasteurization and fat separation. These process steps require a short time only and the denaturation of proteins is negligible, especially when compared with the fish meal process.

We believe that the proteins should be exposed to high temperatures as little as possible. The natural diet is raw fish and the feed should be as close to the natural condition as possible.

From our feed tests, we have found that we require about 2 kgs of feed with 60% TS to produce 1 kg of salmon. To compare with dry feed types, we have to correct for the different water content. The feed factor then will be 1,36 kg with 90% TS for one kg of salmon. This figure represents an average during a period from Sept. until June the following year.

Some results from tests from high and low fat diets are shown on the next page in Figure 8.

From this conclusion we find:

- a correlation between the content of fat and taste,
- that low fat gives a lower weight without reducing the length of the fish noticeably.

The feed is composed of a dry matter part and water. The dry matter consists of protein, fat, carbohydrates, sinews and ash. The ash comes mainly from bones.

Protein, fat, carbohydrates and sinews are the organic components from which fish get the energy for growth, maintenance, activity and metabolism.

Protein is the largest part of the organic compound and the most important nutrition for the fish. Proteins are basic for building up muscles and tissue.

Fat contains elements that are important for forming tissues and for controlling the life process.

Wild fish eat very little carbohydrates and the carbohydrates have probably little or no value. The ash contains minerals that are important, but too large an amount might cause problems, for example with kidneys. Waste from filleting should therefore be used in limited quantities.

A correct feed has a balanced content of energy from fat and protein. The energy absorbed from protein is 3,7 kcal/g or 16,36 kJ/g whereas the energy from fat is 8 kcal/g or 33,47 kJ/g. For a balanced feed, the protein should therefore be about twice as much as the fat.

We suggest that you:

- Reduce the fat content during the growing period, but not so much as to affect the taste.

- Increase the fat content before slaughtering to achieve an ideal weight and quality.

The low fat improves the health of the liver and also the general health condition during the growing period.

During our last control tests at one farm, a test which lasted from October until March, showed the feed factor to have been as low as 1,36 with a concentration in the feed of around 60%.

This means **less than one kg** of dry matter was required to produce one kg of fish.

The feed costs were as **low as \$0,80 US.**

Application of silage concentrate in mink and fox diets

The silage concentrate has been used in diets for mink and fox for the last two years, both in Norway, Sweden and Finland. Previously, it has been found that the addition of raw silage without any concentration had its limitations. The acid content in the concentrate in relation to the dry matter content is considerably less than in raw silage.

Long time tests have been carried out at The Norwegian University of Agriculture concluding that as much as 15% concentrate can be added to the diet without any negative effects. This means that all the frozen fish can be replaced with this concentrate. This will simplify the preparation of feed considerably as the feed kitchen will have a stable concentrate which can be stored in tank silos without any refrigeration.

The available report from the University is a strong recommendation for this type of feed component. There are no negative indications neither on the fur quality and size, nor on reproduction.

Even if a relatively large addition of concentrate has been used, the industry has been careful to replace the fresh frozen offal. Most farmers presently use an

FIGURE 9. RESULTS FROM TESTS FROM HIGH AND LOW FAT DIETS.

LOW FAT

	%	TS	Protein	Fat
Concentrate	82	45,1	24,6	12,3
Fish meal				
Sea weed meal	13	11,7	5,6	0,8
Vitamins				
Binder				
Meal from shrimp shells	5	4,5	2,0	0,2
	100	61,3	32,2	13,3

Energy pr. kg : 2.32 Mcal

Protein energy : 54%

Fat energy : 46%

Feed factor : 2,1 :1

Feed costs per kg salmon \$1.03 US

HIGH FAT

	%	TS	Protein	Fat
Concentrate	82	45,1	20,5	16,4
Fish meal				
Sea weed meal	10	9,0	3,5	0,5
Vitamins				
Binder				
Meal from shrimp shells	8	7,2	3,2	0,2
	100	61,3	27,2	17,1

Energy pr. kg : 2.42 Mcal

Protein energy : 44%

Fat energy : 56%

Feed factor : 1,93 :1

Feed costs per kg salmon \$1.07 US

CONCLUSIONS

	High fat	Low fat
Feed factor (61,3 % DM)	1.93	2.1
Average length of fish	72 cm	69 cm
Average weight	4.38 kg	3.39 kg

addition of 5 to 10%.

Feed for chicken and poultry

We have also had tests carried out with concentrated silage for broilers and egg-laying hens.

The conclusions are that there are no negative arguments compared to the use of fish meal at comparable additive quantities.

Reports from the use on mink, fox and poultry are available for those who might be specially interested.

Fish feeding systems:

Manual feeding for dry, or moist pellets, is extremely laborious and as the feeding depends fully on the operator, there is a high risk of incorrect feeding.

An automated system has been developed for dry and moist pellets.

With this system, the pellets are transported through pipelines with water to each fish cage. Any transport in water will cause loss of feed as some dry material will be dissolved in the water. We have observed that, at many fish farms, the water around the pipeline outlet is quite cloudy with dissolved feed.

We have recently developed a feeding system by which the pasty feed based on silage concentrate is transported by a pump from the feed silo tank to each cage. The system is shown in figures 13 and 14 on the following page. The pelletizer is erected above the cage and the feed drops from the pelletizer into the water. During the transport, there is no use of water and the feed losses are negligible.

The feeding frequency can be adjusted for each cage, but we have found that an almost continuous feeding during the period of daylight gives the best results.

With periodical feeding, the fish will fight for the feed. A lot of feed will be lost and the weak fish, the losers, do not get the feed required.

With almost continuous feeding, the fish do not get excited and do not fight for the feed. It seems quite obvious that we get a more even size and growth for all the fish.

So far we have delivered the system to one fish farm. After some modifications, the equipment has worked

extremely well. So far we have operated feed pipelines with a length of 100 m. The feed tank can be erected either ashore, on a platform, or on a barge.

We are presently working out a data system to register the feed quantity and feed factors for each cage.

I expect that fish farming is only in its infancy. Fish farming, of course, is not new, we know the Chinese have raised fish for the last couple of thousand years.

The production of salmon has increased considerably - in Norway, the largest producer, and also in Scotland, Ireland, Faroe Island, Chile, Iceland, British Columbia and on the east coast of USA and Canada.

Also species like halibut, cod and others will soon be found in fish farms.

To produce one kg of fish, a feed of 5-6 times this weight is required. With the very strong production increase, I believe that the most important limitation will be the supply of feed. It is obvious that any raw material which can be utilized in an economical way should be processed and used as an excellent and high quality feed. A concentrated silage is one alternative which should be seriously considered.◊

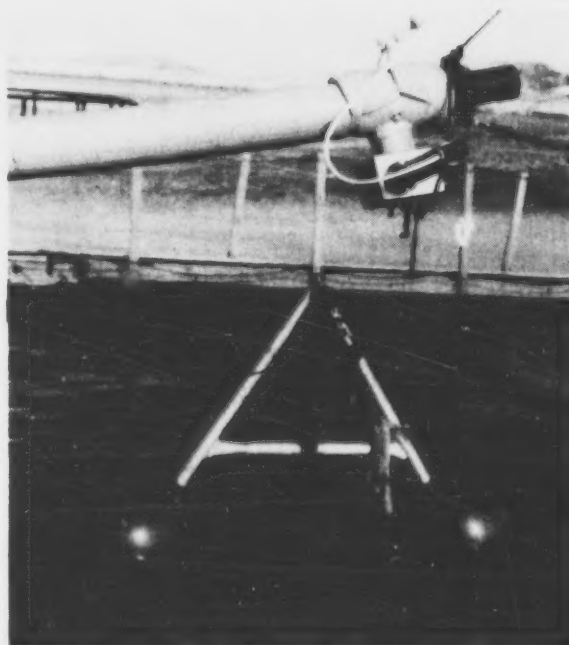
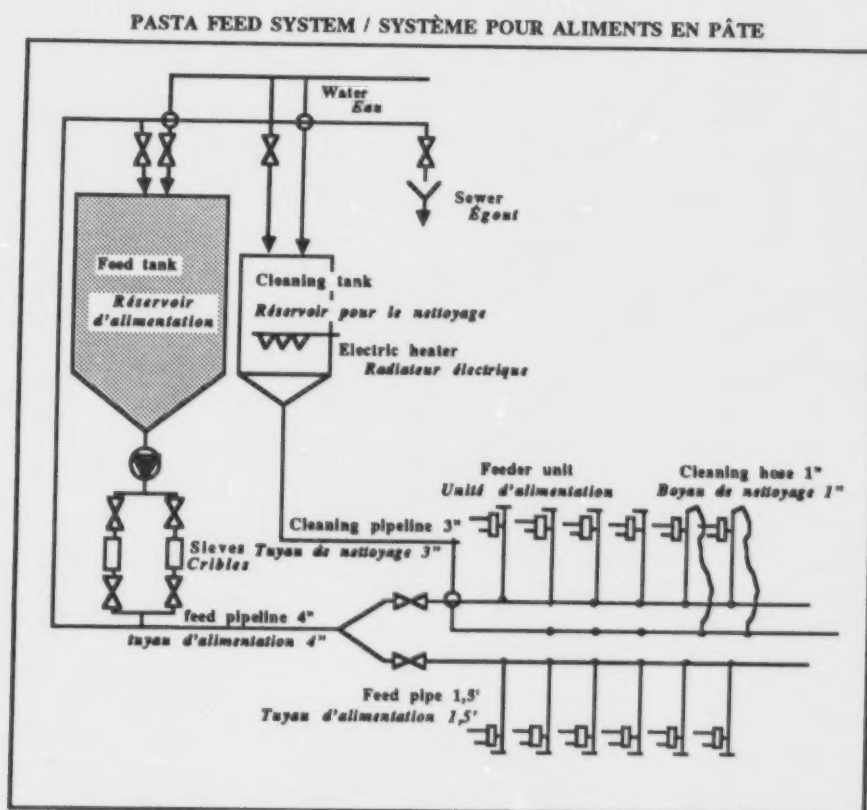


Figure 10. Paste feeder

Figure 11. Paste silo



Figure 12. Pasta feed system



FISH SILAGE AS FEED FOR SALMON AND TROUT

Dr. Santosh P. Lall
Biological Sciences Branch
Department of Fisheries and Oceans
P.O. Box 550
Halifax, N.S.

I. Introduction

In recent years considerable interest had developed in marine culture of Atlantic salmon (*Salmo salar*) and Rainbow trout (*Salmo gairdneri*) in Atlantic Canada. The best area discovered so far for commercial cage culture of Atlantic salmon appears to be the Bay of Fundy off New Brunswick. Three other locations, southern Nova Scotia from Yarmouth to Lockeport, Cape Breton Island and Bay d'Espoir in Newfoundland are also showing potential for Atlantic salmon and rainbow trout culture. The estimated salmonid production for 1986 was 417 tons (Table 1, next page). The projected production for 1987 is estimated to be 1800 tons for both salmon and trout. There are indications that fish production would double by 1990. The growth of this industry has created interest in the utilization of local fishery by-products in salmonid diets.

The natural diet of fish is rich in protein. Generally fish require a higher percentage of protein than do poultry or mammals. The general characteristics of salmonid diets are shown in Table 2 (next page). Fish meal constitutes the major protein source in fish diets. The chemical composition of common marine by-products available in Atlantic Canada is summarized in Table 3. Several research efforts to completely replace fish meal with cheaper plant or single cell proteins in salmonid diets have been unsuccessful. The production of fish meal is both capital and energy intensive, mainly due to the separation of fish such as herring, capelin and white fish etc. into three fractions containing oil, protein and water. However, the manufacture of commercial fish diets often requires the incorporation of fish meal with fish oil.

In eastern Canada, both moist (32-38% moisture) and dry (8-10% moisture) feeds are utilized by the fish farmers. The quality of fish meal produced on the East coast is not yet up to the standard of that produced in Norway. The critical drying process employed during

fish meal manufacture requires careful attention by Canadian producers to retain the desired fish meal quality. Herring and capelin are widely used in moist feed (Table 8) even with problems of continuous supply and expensive frozen storage costs. Fish silage offers the potential of utilizing fishery by-products in a moist type fish feed. In Atlantic Canada, a considerable volume of marine fish and fishery by-products are discarded. Several underutilized fish species are also available. These marine products could be successfully converted into fish silage for use in fish diets. Fishermen and fish farmers situated in isolated areas would particularly benefit from ensiling techniques, where tonnage of fishery by-products is insufficient to justify the production of fish meal and transportation costs are high.

Fish silage based diets have been widely used in Scandinavia for both animals and fish. Silage produced for animal feeds require the separation of oil from silage and strict limits on quantities used to avoid undesirable fish flavours in the flesh. The oil separation step is not necessary for silage used in fish feed because salmonids utilize fish oil efficiently and it constitutes a good source of energy.

II. Raw Materials for Fish Silage

The raw materials suitable for fish silage production may consist of whole, inedible or undersized fish, heads and frames from filleting operations and viscera. The proximate composition of certain whole fish utilized for silage are shown in Table 4. Fishery by-products may contain variable amounts of lipid and protein. The filleting wastes constitute a higher proportion of bones thus requiring a greater concentration of acids for preservation. Proximate composition and gross energy content of some whole fish and viscera silage are summarized in Table 5. The levels of various nutrients differ in these silages and require an adjustment to balance the level of nutrients

Table 1. Mariculture production in Atlantic Canada (1986)

PROVINCE	Rainbow trout	Atlantic salmon
	(metric tonnes)	
New Brunswick	41 (41) ¹	260 (1200)
Newfoundland	19	0,5
Nova Scotia	40 (400)	36 (50)
P.E.I.	10 (12)	-
Quebec	-	11 (30)

¹ Values in parentheses are projections for 1987.
Source: R. Drinnan, DFO, Halifax

Table 2. General characteristics of Atlantic salmon diets

Nutrient	Starter	Grower		Broodstock
		Freshwater	Seawater	
Protein, %	50	44	46	40
Lipid, %	18	14	16 - 20	15
Fiber, %	3	6	6,5	5,5
Ash, %	9,2	8	8,4	7,2
Calcium, %	2,6	2	2	1,9
Phosphorus, %	1,1	1	1,1	1
Digestible Energy (MJ/Kg)	17,9	16,7	17,4	16,3

Table 3. Chemical composition of certain marine by-products

Ingredient	Protein	Lipid	Ash	Gross Energy
	(%)	(%)	(%)	(MJ/Kg)
Herring meal	70,9	9,9	12,4	22,0
Capelin meal	71,8	9,1	8,9	22,2
Whitefish meal	60,1	8,7	25,3	18,4
Shrimp meal	51,1	11,2	19,9	19,6
Crab Protein Concentrate	76,8	0,4	15,9	20,6
Crab meal, A	38,5	4,0	39,9	13,0
Crab meal, B	17,2	2,9	49,4	8,8
Squid, freeze dried	69,3	12,4	7,3	23,7
Euphausiid meal	59,5	8,9	7,9	20,9
Meat & bone meal	47,6	9,4	19,9	18,0

Table 8. Atlantic salmon saltwater grower feed formula (moist)¹

Ingredients	Percentage
Ground pasteurized fish (herring, capelin and other scrap fish)	44,0
Fish meal, herring or capelin (65% crude protein)	27,0
Soybean meal (48% C.P.)	8,0
Wheat middlings (17% C.P.)	13,1
Choline chloride (50%)	0,4
Vitamin premix (CFOH-85mg)	1,0
Mineral premix	0,5
Herring, capelin or salmon oil	6,0

¹ Formula developed and tested by Disease and Nutrition Section, Biological Sciences Branch, Department of Fisheries and Oceans, Halifax, Nova Scotia.

Table 4. Average proximate composition of certain fish (whole species)

Species	Protein	Lipid	Ash	Moisture
	(%)	(%)	(%)	(%)
Herring (<i>Clupea harengus</i>), winter	18,2	8,2	2,0	72,5
Herring, summer	17,1	13,4	1,9	67,8
Capelin (<i>Mallotus villosus</i>)	14,3	10,2	2,1	74,4
Mackerel (<i>Scomber scombrus</i>), spring	17,9	6,1	1,4	74,6
Mackerel, summer	15,1	27,4	1,6	56,4
Dogfish (<i>Squalus acanthias</i>)	18,5	9,1	2,5	70,3
Cod (<i>Gadus morhua</i>)	16,2	3,4	3,1	78,4
Silver hake (<i>Merluccius bilinearis</i>)	17,1	2,3	3,0	78,3

Table 5. Proximate composition and gross energy content of certain fish silages

Silage	Moisture	Protein ¹	Lipid ¹	Ash ¹	Gross ¹ Energy
	(%)	(%)	(%)	(%)	(MJ/Kg)
Herring ²	67,4	47,8	45,6	6,1	28,1
Herring offal ²	66,8	42,7	42,9	8,2	-
Cod ²	77,6	78,8	4,0	16,2	19,2
Whitefish offal ³	78,9	71,1	2,4	19,9	-
Dogfish ²	70,1	73,1	17,6	8,9	22,3
Sprat 2,3	74,3	65,0	24,9	10,5	-
Mackerel 2,3	70,2	56,0	42,6	7,0	-

¹ Dry matter basis
² Whole fish
³ Tatterson and Windsor, 1974

with other feed ingredients in the finished diet.

III. Biochemistry of Silage and Production Principles

Fish silage is commonly defined in the literature as the liquefied product obtained when whole fish or fish processing wastes are ground and mixed with acid or fermentable carbohydrates. Enzymes, present in the fish break down protein and liquify the fish, while acid prevents microbial spoilage. Silage constitutes a good source of protein and lipid in the ration on fish and several domestic animals.

Generally, two methods are used in silage production, ensiling through chemical acidification (acid preserved silage) or bacterial fermentation (fermented silage). A different product "fish protein hydrolysates", where controlled hydrolysis of fishery wastes by the addition of selected exogenous enzymes, has also been developed. In acid preserved silage, inorganic and/or organic acids are commonly employed in silage production (Table 6). For production of fermented silage, bacterial fermentation is initiated by the addition of lactic acid bacteria and fermentable carbohydrates to minced fish. The lactic acid bacteria are naturally present in fish and often starting culture is not necessary. Studies on the nutritional value of fermented silage for fish are limited.

Although, inorganic acids (sulfuric and hydrochloric) are relatively strong and economical, the final pH of

silage must be approximately 2, to prevent bacterial spoilage (Edin, 1942). Such silages must be neutralized with chalk or other binder mixtures prior to feeding (Peterson, 1953). On the other hand, organic acids possess much better anti-bacterial properties and Stable Silages have been obtained with formic and propionic acids (Gilberg and Raa, 1977). Often, a mixture of inorganic and organic acids are used to sufficiently lower pH at low cost and prevent microbial spoilage (Table 6). Propionic acid prevents mould (*Aspergillus flavus*) growth (Strom *et al.*, 1980) and particularly useful for silage stored at higher temperatures.

Liquefaction (autolysis) of fish silage is determined by the activity of digestive enzymes in the raw material, pH, composition of raw material (lipid, protein and moisture), temperature and the level of acid incorporated. Proteases are responsible for autolysis. The digestive proteases have an optimum pH range of 2 to 4 and their activity decreases sharply above pH 4. Approximately, 80% of the protein in acid preserved silage becomes solubilized after one week or temperatures 23° to 30°C (Gilberg and Raa, 1977; Backhoff, 1976; Tatterson and Windsor, 1974). The yield of solubilized protein depends on the type of raw material. The muscle yields a low amount of soluble protein because the level of proteolytic enzyme activity is low in this tissue. The rate of autolysis and yield of soluble protein is highest in viscera.

During liquefaction, the majority of proteins are converted to short peptides, a portion of which may be

Table 6. A summary of several studies employing various acids to produce stable silages of given pH from fishery by-products

Raw material	Type and level of acid added (%)	Acid Ratio (v/v)	pH of silage	Reference
Herring <i>Clupea harengus</i>	Formic (2) ¹	-	4	Jensen and Schmidtsdorf, 1977
Herring <i>Clupea harengus</i>	Formic (3)	-	3,8-4,1	Lall and Hines, 1987
Herring <i>Clupea harengus</i>	Formic and sulphuric (3)	1:1	3,5-3,8	Lall and Hines, 1987
Herring offal	Formic (1,62)	-	4,4	Olsson, 1942
Dogfish <i>Squalus acanthias</i>	Formic and Sulphuric (3)	1:1	3,6-3,9	Lall and Hines, 1987
Cod <i>Gadus morhua</i>	Formic and Sulphuric (3)	1:1	3,8-4,4	Lall and Hines, 1987
Cod and Saithe <i>Pollachius virens</i>	Formic and Propionic (1,5)	1:1	4,5	Strom and Eggum, 1981
Coalfish <i>G. virens</i> and Capelin <i>Mallotus villosus</i>	Formic and Propionic (3)	5:1	4,1	Rungruangsak and Utne, 1981
Coalfish <i>G. virens</i> and Capelin <i>Mallotus villosus</i>	Hydrochloric and Propionic (3)	5:1	4,4	Rungruangsak and Utne
Coalfish <i>G. virens</i> and Capelin <i>Mallotus villosus</i>	Sulphuric and Propionic (3)	5:1	3,3	Rungruangsak and Utne, 1981
Sprats <i>Sprattus sprattus</i>	Formic and Sulphuric (3)	1:1	3,8-4,2	Jackson <i>et al.</i> , 1984
Pacific Whiting <i>Theragra chalcogrammus</i>	Sulphuric and Propionic (3)	2:0,75	-	Hardy <i>et al.</i> , 1984
Pacific Hake <i>Merluccius productus</i>	Phosphoric	-	3,6-3,7	Timmerman, 1978

¹ Values in parentheses indicate the level of acid added.

hydrolysed to free amino acids. Ash (1980) reported that amino nitrogen is utilized more readily from peptides (2-6 amino acids) than the corresponding free amino acids. When autolysis is allowed to continue, the percentage of nitrogen as free amino acid increases while the percentage of nitrogen as polypeptide further decreases (Stone and Hardy 1986). High levels of free amino acids in diets containing older silage may interfere with the mechanisms of both amino acid and polypeptide absorption. Further degradation of free amino acids produces ammonia and causes losses of essential amino acids such as tryptophan, phenylalanine, tyrosine and arginine. Stone and Hardy (1986) demonstrated that restricting the autolysis of fish protein for less than 1 hour at 60°C at physiological pH (6.2-6.6) and then pasteurization (90°C for 30 min.) and acidification to pH 4 produces polypeptides of intermediate length. These liquefied proteins are more stable and better utilized than conventional silage.

The high level of unsaturated lipids in the oil of fish silage makes it susceptible to oxidation and formation of hydroperoxides and secondary breakdown products. Feeding of oxidized lipid to fish causes the reduction of food intake by the decreased palatability resulting from off flavours and destruction of nutrients in the diet prior to feeding or in the gastrointestinal tract itself. The addition of an antioxidant such as ethoxyquin (250 ppm) to the silage inhibits the formation of oxidation products (Jackson et al., 1984). During storage, the breakdown of triglyceride to free fatty acids (6 - 8%) has been reported (Tattersen and Windsor, 1974). However, Austreng and Gjefson (1981) showed that the level of free fatty acids (up to 11%) in the lipid used for salmon diets did not affect either the nutrient digestibility or the growth of fish.

It has been shown that a wide range of marine and freshwater fish species contain a thiamin-destroying enzyme, thiaminase (Greig and Gnaedinger, 1971). Recently, Anglesea and Jackson (1985) reported that thiaminase activity persists immediately after ensilation. The activity was significantly reduced by extended storage (56 days) of silage at ambient temperature. The mixing of silage into a moist diet with a dry binder meal further reduced the thiamin destruction. The loss of thiamin in silage is generally overcome by the addition of extra thiamin in the vitamin supplement.

It is generally accepted that most micro-organisms are destroyed during the liquefaction process. The survival of disease organisms including viruses, parasites and bacterial pathogens in silage has not been tested. Also, the stability of the botulin toxin, which may occur in raw materials prior to ensiling has not been examined. In order to avoid transfer of

infectious agents through feed, the pasteurization of silage is often recommended.

IV. Nutritional Values of Acid Preserved Silage

In recent years several workers have successfully utilized acid preserved silage obtained from Spratt (Jackson et al., 1984a, b), Coalfish, Capelin (Rungruangsak and Utne, 1981), pacific whiting (Hardy et al., 1984; Stone and Hardy, 1986), dogfish, herring, cod (Lall and Hines, 1987), dogfish offal (Asgard and Austerang, 1985), trash fish (Austerang and Asgard, 1986) and Shrimp waste (Tidemann et al., 1983), in salmonid diets. Rungruangsak and Utne (1981), using diets containing 60% silage preserved with hydrochloric acid, observed growth in rainbow trout equivalent to a diet of fresh fish. Similarly, good results have also been reported in rainbow trout and Atlantic salmon (Asgard and Austerang, 1981 and Jackson et al., 1984b). Although, a characteristic softening of the gut has been noted in Norwegian fish farms, no adverse effect on the general performance and flesh quality have been reported.

Silage produced from propionic acid (0.5%) or its combination with either formic or sulphuric acid are not palatable to Atlantic salmon (Austreng and Asgard, 1986). However, rainbow trout fed diets containing the same silage preserved with propionic acid did not show food aversion and growth depression (Table 7, next page). Rungruangsak and Utne (1981) reported that formic and sulphuric acid caused a reduction in the protease activity of the digestive tract and growth depression particularly at the higher level of incorporation into the diet. These effects were not apparent in groups fed hydrochloric acid silage based diets. However, any adverse effects of feeding fish silage preserved with formic acid and/or sulphuric acid on growth and food intake have not been observed in either rainbow trout and Atlantic salmon by other workers (Austreng, 1982; Jackson et al., 1984a, b and Lall and Hines, 1987).

Our recent work on the apparent digestibility and digestible energy content of silage produced from whole herring, dogfish and cod are summarized in Table 9. Results clearly indicate that all three types of fish silage are efficiently utilized by Atlantic salmon. The protein and lipid digestibility of all silage based diets was significantly higher than raw fish. The lipid from herring is efficiently absorbed by Atlantic salmon. The high lipid content of herring contributed towards its higher digestible energy content among all these fish species. Dogfish also contains a good source of food energy for Atlantic salmon.

Table 7. Average weight gain of Atlantic salmon and Rainbow trout fed diets containing fish silage for 124 days. ¹

Diet No.	Acid for Preservation	pH of silage	Weight gain ² (g)	
			Atlantic salmon	Rainbow trout
1	Formic (2,2%)	4,4	580	930
2	Formic (1,1%) + Propionic (1,1%)	4,8	-150	925
3	Sulphuric (2,5%) + Formic (1,1%)	3,9	485	840
4	Sulphuric (2,5%) + Propionic (1,1%)	4,1	-65	710
5	Sulphuric (2,5%) + Acetic (1,1%)	4,2	270	830
6	Raw fish ³	-	380	975

¹ Data from Austreng and Asgard, 1986

² Initial weight: Atlantic salmon 1700 g; Rainbow trout 1800 g.

Table 9. Apparent digestibility co-efficients and digestible energy (D.E.) values of various fish and their silage

Ingredient	Crude Protein	Lipid	Digestible Energy	D.E. Value
	(%)	(%)	(%)	(MJ/Kg)
Whole Fish				
Herring	94,1	94,0	81,5	23,6
Dogfish	91,1	90,1	80,2	19,1
Cod	93,4	92,8	81,5	15,6
Silage (Formic and Sulphuric Acid)*				
Herring	93,8	95,9	85,8	24,1
Dogfish	93,5	93,6	84,0	18,9
Cod	91,3	92,2	80,9	15,1
Silage (Formic Acid)*				
Herring	94,0	95,5	86,1	24,4

*Formic Acid or Formic and Sulphuric Acid at 3%

V. Feed Processing

A. Manufacturing

Moist pellets containing variable amounts of fish silage or frozen fish together with dry ingredients, binders, vitamins and mineral mixtures are cold pelleted or extruded. The moisture content of the diets is sometimes as high as 50 percent. The moist feed must

be used immediately or kept frozen until fed. Improper storage of such diets can severely affect the stability of vitamins and lipid. There is a rapid loss of ascorbic acid in moist feed. Salmonid fish prefer moist pellets as compared with dry feed because of their softness and palatability. Some of the advantages and disadvantages of moist and dry pellets are listed in Table 10.

B. Food binders

Diets containing silage require binders to achieve the proper integrity of pellets. The binding agent prevents moist pellets from disintegrating in the water and thereby reduces the loss of feed and water pollution. Common feed binders incorporated into fish diets include alginates, guar gum, starch, gelatin, carboxymethyl cellulose and agar. Alginates are salts of alginic acid extracted from seaweeds, which is a β -1, 4-D-mannuronic and α -1, -4-1-guluronic acid polymer. Both the -OH and -COOH groups of the molecules possess active binding capacity, resulting in thickening and gelling of food products. Guar gum derived from the endosperms of the Indian cluster bean, is a water soluble polymer of β -1, r-D mannose and β -1-4, -D-galactose with some α -1,6 side chains. The -OH groups of the molecules are responsible for the viscosity and thickening of food. Both guar gum and alginates are known to reduce the apparent digestibility of protein and fat and increase the moisture content of feces (Storebakken, 1985).

VI. Storage

Fish silage is a relatively stable product provided an adequate level of antioxidant is added to prevent oxidation and rancidity of fish oil. Although some reports indicate that fish silage could be stored from 6 months to a year, the quality of the silage should be monitored frequently to insure proper nutritional characteristics. The loss of the essential amino acid tryptophan in fish silage is more common particularly after storage at high temperatures (30°C). Another essential amino acid, histidine, may be limiting in fish

silage prepared from partly spoiled fish and stored for longer periods.

The silage separates into three phases during storage: fish oil floating at the top, highly soluble protein and minerals in the middle layer and partially soluble materials at the bottom. Proper mixing and stirring is essential to avoid oxidation of the lipid fraction and to maintain the quality of the product.

VII. Market Potential

The estimated demand for fish feed in Atlantic Canada may reach 7,000 tonnes by 1990. The superior performance of Atlantic salmon on moist feed appears to have increased the demand for herring and other fishery by-products. It is likely that some herring carcasses discarded from the herring roe fishery will be utilized in silage production, thus turning a waste-product into a useful feed ingredient.

In contrast to animal feeds, the demand for fish feed is seasonal peaking in warmer months. Approximately, 70-80% of the total yearly food requirements of Atlantic salmon reared in sea cages is consumed from June to October (Figure 1, next page). It parallels the supply of most raw materials i.e. herring and capelin. The acid preserved silage produced in fall from these fishery by-products could be successfully utilized for winter and early spring feeding.

Table 10. Relative advantages of dry, moist, and silage based diets

Criteria	Dry	Moist	Silage
Cost	***	**	**
Automated Feeding	***	**	**
Handling	***	*	*
Transportation	***	*	*
Storage	***	*	*
Continuous Availability	***	**	**
Uniformity of Pellets	***	**	**
Leaching of Nutrients	***	**	**
Water Quality	***	**	**
Disease Transmission	***	**	**
Rancidity/Nutrient Loss	**	***	***
Acceptability 10-16° C 1-7° C	*	***	***

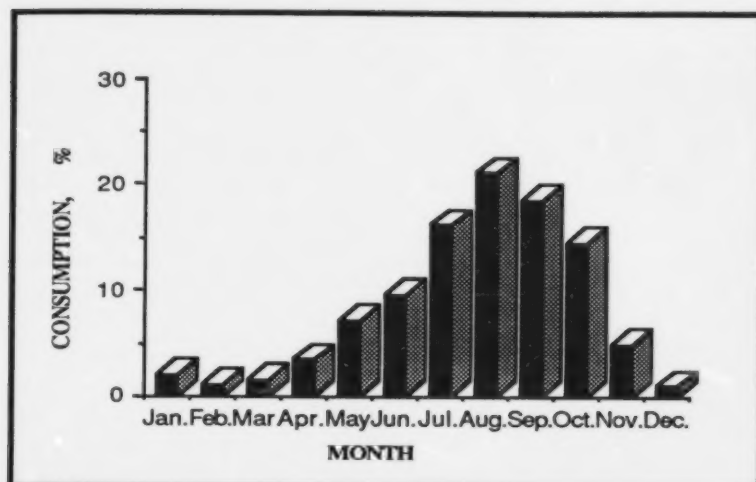


Figure 1

VIII. Conclusions

A wide variety of underutilized fish species and marine by-products is available in Atlantic Canada for use in aquaculture feeds. The demand for fish meal and fish oil in North America is also increasing sharply. There are indications that herring and capelin meal produced in Eastern Canada may be in short supply. The conversion of fish protein discarded as waste into fish silage may be an effective way of salvaging some of these resources. More research efforts are needed to improve the nutritional quality of these marine by-products and extend their storage properties. New developments to reduce the moisture content of fish silage would further encourage an efficient use of this product in moist feed formulations.◊

References

- Anglesea, J.D. and Jackson, A.J. (1985). *Aquaculture* 13, 39-46.
- Ash, R.H. (1980). *Comp. Biochem. Physiol.* 65B, 173-176.
- Asgard, T. and Austreng, E. (1985). *Aquaculture* 49, 289-305.
- Asgard, T. and Austreng, E. (1981). *Feedstuffs* 53, 22-24.
- Austreng, E. (1982). *Aktuelt fra statens fagteneste i landbruket (Husdyrforsoksmotet 1982)*, Norwegian Agriculture University, 525 p.
- Austreng, T. and Asgard, E. 1986. In "Trends and Problems in Aquaculture Development", (E. Grimaldi and H. Rosenthal, ed.), 218-229, Ente Autonomo Fierde di verona, Verona, Italy.
- Austreng, T. and Gjefson, T. (1981). *Aquaculture* 25, 173-183.
- Backhoff, H.P. (1976). *J. Food Technol.* 11, 253-263.
- Edin, H. (1940). *Nord. Jordbr. Forsk.* 22, 142.
- Gilberg, A. and Raa, J. (1977). *J. Sci. Food Agric.* 28, 647-653.
- Greig, R.A. and Gnaedinger, R.H. (1971). U.S. Fish Wildl. Ser. Spec. Scient. Rep. Fish. No. 631.
- Hardy, R.W., Shearer, K.D. and Spinelli, J. (1984). *Aquaculture*, 38, 35-44.
- Jackson, A.J., Kerr, A.K. and Cowey, C.B. (1984a). *Aquaculture*, 38, 211-220.
- Jackson, A.J., Kerr, A.K. and Bullock, A.M. (1984b). *Aquaculture*, 40, 283-291.
- Jensen, J. and Schmidtsdorff, W. (1977). In "Symposium on the production of fish meal" pp. 23-26. International Assoc. Fish meal Manufacturers, Hertfordshire, U.K.
- Lall, S.P. and Hines, J.A. (1987). Unpublished report.
- Olsson, N. (1942). *Landbrukshogskolan Husdjurforsoksanstalten*. Sweden, Report No. 7, pp. 55.
- Peterson, H. (1953). *FAO Fish. Bull.* 6, 18 pp.
- Rungruangsak, K. and Utne, F. (1981). *Aquaculture*, 22, 67-79.
- Stone, F.E. and Hardy, R.W. (1986). *J. Sci. Food Agric.* 37, 797-803.
- Storebakken, T. (1985). *Aquaculture*, 47: 11-26.
- Strom, T. and Eggum, B.O. (1981). *J. Sci. Food Agric.* 32, 115-120.
- Strom, T., Gildberg, A., Stormo, B. and Raa, J. (1986). In "Advances in Fish Science and Technology" (J.J. Connell, ed.), p. 352-355. Fishing News Books.
- Tatterson, I.N. and Windsor, M.L. (1974). *J. Sci. Food Agric.* 25, 369-379.
- Tidemann, E., Raa, J., Stormo, B. and Torrisen, O. (1983). In "Engineering and Food", Proc. Int'l Congress Engineering and Food, 1983, (McKenna, B.M. ed.), 583-594, Elsevier Applied Science, London, U.K.
- Timmerman, C.D. (1977). M.Sc. Thesis. Oregon State University, U.S.A.

FISH SILAGE AS ANIMAL FEED

T.A. Van Lunen
Acting Superintendent
Agriculture Canada
Research Branch
Nappan, N.S.
BOL 1CO

Introduction

Fish silage is by no means a new product, having been produced and used for years on a limited basis, especially in Scandinavia. Recently it has gained a great deal of attention in many parts of the world, and especially Eastern Canada, as a means of reducing production costs (as opposed to fish meal) and utilizing trash fish and fisheries' wastes which are creating environmental problems.

In Nova Scotia fish silage is being considered as a possible method of utilizing the large quantities of herring discarded from the herring roe industry.

My presentation today will be a review of present knowledge regarding the utilization of fish silage by livestock.

Market Potential In Atlantic Canada

The major livestock species to be considered as potential fish silage consumers are beef cattle, dairy cattle, sheep, poultry, pigs and fur bearing animals. Of these, pigs and fur bearers constitute the largest market. Beef cattle, dairy cattle and sheep consume a large portion of their diet in the form of roughage such as grass, hay and silage and require little if any supplemental protein. In addition to this, there is some

concern that fish products fed to dairy cattle may impart fishy flavours to milk. Poultry require high protein diets, however, the present level of mechanization in poultry houses does not allow for liquid or semi-liquid feed consistencies. Due to the above, I will not present statistics on the potential markets for fish silage for these animals, but rather concentrate on pigs and fur bearing animals.

As can be seen in Table 1 there are over 100,000 mink, 28,000 foxes and 668,000 pigs in existence in

Graph A

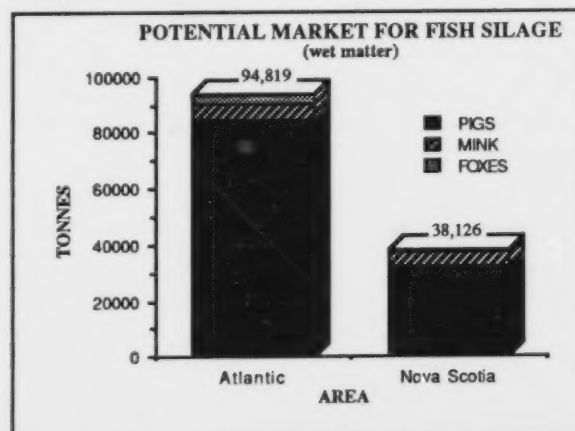


Table 1

STATISTICS					
	NS	NB	PEI	NFLD	TOTAL
Mink*	90951	4308	7968	3114	106,341
Foxes*	9051	11103	7180	914	28,248
Pigs**	250,000	190,000	200,000	28,000	668,000
/YEAR - *January, 1986. ** April, 1987					

Atlantic Canada in a given year. This represents 3500 T of fish silage for foxes and 5800 T for mink at 30% dry matter (DM) of the diet and 85,500 T per year for pigs at 10% (DM) of the diet (Graph A). From the above it is apparent that large quantities of fish silage could be utilized in Atlantic Canada if no constraints existed.

Review of Literature

Although pigs and fur bearing animals offer the greatest potential market for fish silage in Atlantic Canada, other livestock can utilize some of this product. Winter and Feltham (1983) report that ruminant animals such as beef and dairy cattle, as well as sheep, degrade fish protein into amino acids and peptides, thus reducing its value as compared to monogastric animals such as pigs. Because of the fermentation which occurs in the rumen, the amino acids in fish silage will be quickly degraded and the nitrogen lost under normal dietary conditions. Johnson and Ekern (1982) suggest the addition of formaldehyde to fish silage to reduce the amino acid degradation. Shqueir et al. (1984) and Johnson and Ekern (1982) report that supplementation of fish silage improves digestibility of diet organic matter, protein and crude fiber. Wet et al. (1982) reports that fish silage can be incorporated in lamb milk replacers with no detrimental effects on growth and well-being after an initial adjustment period.

Krogdahl (1985) reports that chicks, ducks and laying hens fed fish viscera silage performed as well as those on a control diet containing no fish silage. No negative effects were found in egg or meat quality, however, it was determined that hens could not be fed levels of fish silage higher than 20% of protein replacement without detrimental effects on growth and egg production.

Green et al. (1983) reports that fish silage offers good nutrient value for pigs. For example, fish silage made from whiting contained 16.5 MJ/kg DM metabolisable energy, 74.1% DM crude protein and 84% nitrogen digestibility. Winter and Feltham (1983) suggests that fish silage is a good protein source for pigs, however, it must not contain more than 1.0% fat (wet basis) to avoid meat quality problems. Coxon et al. (1986) suggests that long chain polyunsaturated fatty acids present in fish silage are laid down in pork fat and are responsible for oily and fishy flavours.

According to Winter and Feltham (1983) fish silage used in fur animal diets is limited as both foxes and mink are sensitive to diets with a low pH. Mink can tolerate a pH of 5.5 in the total diet while foxes require pH 5.8. Levels of 10 to 30% fish silage (DM) are fed to

mink and foxes during the growing period, however it is suggested that it be removed from the diet during the breeding season.

Experiments

From the literature reported above regarding the feeding of fish silage to pigs; several experiments were conducted to further evaluate fish silage as a protein source for pigs.

Experiment 1

Experiment 1 was designed to determine what levels of fish silage can be incorporated into the diet of the pig and if those levels can be increased by the addition of a sweetener such as liquid glucose.

One hundred and ninety-two pigs were randomly placed in pens of 12 on one of four treatments. The experiment was replicated twice. The experiment was designed as a 2 x 2 factorial with two levels of fish silage (10% DM and 15% DM) and two sweetener treatments (addition of glucose and no sweetener added). As well, the pigs on this test were compared to a control group fed no fish silage. The pigs were housed in concrete floored pens, either in an open front barn or a conventional facility. Water was provided ad libitum while feed was made available on the floor twice per day to appetite. Weight gain was monitored weekly while feed consumption was calculated daily.

The fish silage was manufactured in lots of two to three tonnes. Offal was obtained from a local fish processor either in a fresh or frozen state. It was ground immediately upon arrival and placed in 150 litre plastic drums. Formic acid was added to the ground offal at 3.5% by weight and then stirred with a wooden paddle. After sitting at room temperature for 3 to 5 days, the treated offal maintained a steady pH in the range of 4.2 at which time it was ready to be fed.

The mixed diets containing fish silage were prepared daily. (See Tables I-IV on next page). These diets were mixed in small quantities in a portable cement mixer and then carried in buckets to the pens.

The effects of feeding fish silage on growth performance of pigs are shown in Table VI. As can be seen in the table, the starting weight, market weight and total gain of the pigs were similar for all treatments. Significant differences between treatments were apparent in growth rate. Days on test were significantly less ($P < 0.05$) for the 10% fish silage treatments as compared to the 15% fish silage pigs. Gain per day was significantly higher for the 10% treatments over the 15% treatments. No effects on growth performance were observed from the addition of glucose to the

Figure I: Feed Formulation F10G

Ingredient	% in Diet
Corn	54,3
Oats	25,0
Soybean meal (48%)	5,2
Fish silage	10,0
Vitamin-mineral premix	1,0
Dicalciumphosphate	1,0
Salt	0,4
Glucose	3,1
Analysis	%
Crude protein	15,3
Crude fibre	3,9
Ca	1,2
P	0,9
Metabolizable energy (calculated)	3156 Kcal/kg

Figure II: Feed Formulation F10NG

Ingredient	% in Diet
Corn	57,0
Oats	25,1
Soybean meal (48%)	10,0
Fish silage	5,2
Vitamin-mineral premix	1,0
Dicalcium phosphate	1,0
Salt	0,4
Tallow	0,3
Analysis	%
Crude protein	15,8
Crude fibre	4,0
Ca	1,3
P	0,8
Metabolizable energy (calculated)	3187 Kcal/kg

Figure III: Feed Formulation F15G

Ingredient	% in Diet
Corn	54,5
Oats	25,1
Fish silage	15,0
Vitamin-mineral premix	1,0
Dicalcium phosphate	1,0
Salt	0,4
Glucose	3,0
Analysis	%
Crude protein	15,7
Crude fibre	3,9
Ca	1,4
P	0,9
Metabolizable energy (calculated)	3163 Kcal/kg

Figure IV: Feed Formulation F15NG

Ingredient	% in Diet
Corn	57,0
Oats	25,2
Fish silage	15,0
Vitamin-mineral premix	1,0
Dicalcium phosphate	1,0
Salt	0,4
Glucose	0,4
Analysis	%
Crude protein	16,2
Crude fibre	4,1
Ca	1,3
P	0,9
Metabolizable energy (calculated)	3194 Kcal/kg

Figure V: Analysis of Fish Silage

	Mean	Range
pH	4,13	3,80 - 4,60
Crude Protein	64,57%	61,81 - 70,68
Dry matter	19,62%	18,74 - 21,20

diet.

Feed consumption of the pigs on test is shown in Table VII. Total feed consumption was significantly higher ($P < 0.05$) for the 15% fish silage treatments over

the 10% treatments. No differences existed between treatments for daily feed consumption while feed efficiency (feed/gain) was significantly poorer ($P < 0.05$) for the 15% fish silage treatments. No effects on feed consumption by the addition of glucose to the diet were observed.

The effects of feeding fish silage to pigs on carcass quality are shown in Table VIII. As can be seen, feeding 10% or 15% fish silage, with or without the addition of glucose, had no effect on dressed weight, dressing percent, loin fat thickness or carcass quality index.

From the results obtained in this test, it is apparent that

Figure VI: Growth Performance

	Starting Wt (kg)	Market Wt (kg)	Gain (kg)	Days	Gain/Day (kg)
F10G ¹	21.23 ²	97.21	75.96	113.42 a	0.68 a
F10NG	21.17	97.50	76.31	115.67 a	0.67 a
F15G	21.91	96.90	75.58	121.89 b	0.62 b
F15NG	21.57	96.72	75.13	122.06 b	0.62 b
Control	21.49	97.10	75.61	109.57 a	0.69 a
Significance	NS	NS	NS	P<0.05	P<0.05
F10	21.20	97.36	76.14	114.54 a	0.68 a
F15	21.74	96.81	75.13	121.98 b	0.62 b
Control	21.49	97.10	75.61	109.57 a	0.69 a
Significance	NS	NS	NS	P<0.05	P<0.05

¹F10G = 10% fish silage with glucose

F10NG = 10% fish silage with no glucose

F15G = 15% fish silage with glucose

F15NG = 15% fish silage with no glucose

²Values with different letters are statistically different (P<0.05).

Figure VII: Feed Consumption¹

	Total Feed/Pig (kg)	Feed/Pig/Day (kg)	Feed/Gain (kg)
F10G ²	230.98 a ³	2.00	3.04 a
F10NG	229.78 a	1.97	3.01 a
F15G	260.64 b	2.14	3.45 b
F15NG	164.60 b	2.18	3.52 b
Control	242.71 ab	2.22	3.21 ab
Significance	P<0.05	NS	P<0.05
F10	230.38 a	1.99	3.02 a
F15	262.63 b	2.16	3.49 b
Control	242.71 ab	2.22	3.21 ab
Significance	P<0.05	NS	P<0.05

¹Based on 87.0% dry matter.

²F10G = 10% fish silage with glucose

F10SG = 10% fish silage with no glucose

F15G = 15% fish silage with glucose

F15SG = 15% fish silage with no glucose

³Values with different letters are statistically different (P<0.05).

Figure VIII: Carcass Quality

	Dressed Wt (kg)	Dressing %	Loin Fat (cm)	Index
F10G ¹	77.55	79.58	3.10	105.2
F10NG	78.29	80.39	3.07	105.5
F15G	77.53	79.76	3.02	105.5
F15NG	77.44	79.88	2.97	106.3
Control	77.39	79.70	2.96	105.1
Significance	NS	NS	NS	NS
F10	77.92	79.98	1.21	105.4
F15	77.48	79.82	1.18	105.9
Control	77.39	79.70	2.96	105.1
Significance	NS	NS	NS	NS

¹F10G = 10% fish silage with glucose
 F10NG = 10% fish silage with no glucose
 F15G = 15% fish silage with glucose
 F15NG = 15% fish silage with no glucose

fish silage can be used as a protein source for feeder pigs. The addition of glucose as a sweetener had no effect on growth performance or feed consumption. In fact, it appears that palatability of the fish silage was not the problem at either 10% or 15% fish silage in the diet. Growth rate was set back by feeding the 15% fish silage level although feed consumption was unaffected. It appears that at the higher level, the protein provided by the fish silage was not utilized as well. This is demonstrated not only in a depressed growth performance, but also in poorer feed efficiency. A digestibility trial presently under way will provide more answers regarding this result.

The 10% level of fish silage appears to be a suitable alternative to common diets presently using soybean meal as a protein source. In all cases, results of the 10% fish silage treatment were similar to the control.

Carcass quality appears to be unaffected by level of fish silage in the diet.

It can be concluded from the results of this experiment that fish silage incorporated in the diet of feeder pigs at 10% (dry matter basis) of the diet is a good protein source for swine.

Experiment 2

This experiment was conducted to evaluate the effects of fish silage on pork quality. A total of 40 pigs were placed on test at a mean starting weight of 20 kg and randomly placed 8 per pen in 5 pens; each pen being a separate treatment. From each pig 12 separate meat samples (lean and fat) were taken. Each treatment consisted of a withdrawal of fish silage from the diet prior to slaughter as shown below:

- OD - no withdrawal of fish silage
- 1OD - fish silage withdrawn 10 days prior to slaughter
- 2OD - fish silage withdrawn 20 days prior to slaughter
- 4OD - fish silage withdrawn 40 days prior to slaughter
- Control group - no fish silage in the diet

All pigs except those on the control diet were fed the same diet containing 10% fish silage which contained 2% fat on a wet basis. (See diet formulation from Experiment 1.) Pigs were slaughtered at a mean weight of 100 kg at which time meat samples were taken. These samples were frozen at -30°C for up to 30 days at which time they were shipped to the Technical University of Nova Scotia (TUNS) for taste panel evaluation. The panels evaluated pork samples 30 days and 180 days post slaughter. The samples frozen for 180 days were stored at -18°C (except for some control samples which continued to be stored at -30°C)

to allow oxidation to occur if there was a tendency for it to take place.

Since this test has just been completed, statistical analysis of the data is not available. The following comments are from a cursory view of the raw data.

In the first evaluation (30 days post slaughter), none of the panelists could detect fishy flavours or other strong "off" flavours in any of the samples.

In the second evaluation (180 days post slaughter), one sample of the OD treatment and one sample of the 1OD treatment were found to have fishy flavours, however numerous "off" flavours were identified in many samples across all treatments. Rancid flavours were found in one OD sample only.

From this experiment it appears that there may be some concern regarding possible meat quality problems from pigs fed fish silage although these appear minimal. Fatty acids have been named as the main culprit in off flavours of pork and it should be noted that the fish silage used in this study contained twice the recommended fat level.

Recent reports have indicated that oil extraction of fish silage is possible and if this were utilized to keep the fat level below 1%, it may be that fish silage can be fed to pigs with little or no negative effects on meat quality.

Application to Atlantic Canada

From the literature and research results reported above, it is apparent that many classes of livestock can be fed fish silage. The constraints limiting its use in Atlantic Canada are monetary in nature. Three constraints need to be overcome: (1) cost of production of fish silage; (2) cost of transportation of fish silage and (3) cost of feeding and storage systems on farms.

If the cost of production and transportation can be low enough to keep the price of fish silage below competitive protein sources, farmers such as pork producers will be interested in the product. Under present feed pricing conditions, it is estimated that 20% dry matter fish silage could not exceed \$60.00 to \$70.00 per tonne delivered to the farm.

At present, agriculture personnel are investigating inexpensive and efficient methods of storing, mixing and feeding fish silage diets to pigs.

If the constraints listed above can be overcome, fish silage will become a common and desired feed source in Atlantic Canada.◊

Literature Cited

- Coxon, D.T., Peers, K.E. and Griffiths, N.M. 1986. Recent observations on the occurrence of fishy flavour in bacon. *J. Sci. Food Agric.* 37, 867-872.
- Green, S., Wiseman, J. and Cole, D.J.A. 1983. Fish silage in pig diets. *Pig News and Information* Vol. 4(3).
- Johnsen, F. and Ekern, A. 1982. Effect of fish viscera silage on the rumen metabolism of sheep. *Acta Agric. Scand.* 32.
- Krogdahl, A. 1985. Fish viscera silage as a protein source for poultry. *Acta Agric. Scand.* 35.
- Shqueir, A.A., Kellems, R.O. and Church, D.C. 1984. Effects of liquified fish, cottonseed meal and feather meal on in vivo and in vitro rumen characteristics of sheep. *Can. J. Anim. Sci.* 64: 881-888.
- Wet, P.J., Wessels, J.P.H. and Post, B.J. 1982. Utilization of fish silage as an important protein source in a milk replacer for lambs. *Fisheries Industry Research Institute, Capetown, S.A. Annual Report.*
- Winter, K.A. and Feltham, L.A.W. 1983. Fish silage: the protein solution. *Agriculture Canada Report.*

OVERVIEW OF FISH WASTE UTILIZATION PROGRAMS

Georges Richard
Director, Industrial Development
Nova Scotia Department of Fisheries
Halifax, N.S.
B3J 3C4

Within our Department, the fish waste problem is a priority, in part because it is current and highly visible. This problem is by far the most serious in the herring roe fishery in this part of the province. In this fishery, more than 20,000 tons of herring carcasses are dumped every year in landfill sites or at sea. This problem will get worse as more municipalities prohibit landfill sites.

Dumping of herring on such a scale creates 3 types of problems:

1. environmental concerns, particularly due to seepage of herring oil,
2. additional costs to processing companies, rather than providing opportunities for value-added processing,
3. moral or political outcries from the gross waste of such a food resource.

This bizarre situation exists because:

- a. Local fish meal plants cannot handle these large volumes, and it appears financially unattractive to construct or expand such plants for only a 6 week operating season.
- b. International markets for food herring products are relatively weak due to the recovery of European stocks.
- c. Much of the herring is unfit for human consumption after the roe has been removed.

We, and various companies, are therefore examining a wide variety of options for dealing with this waste problem, of which silage is only one alternative. These include:

1. increasing fish meal capacity by
 - expansions or new plants and/or
 - raw material storage to extend processing season
2. development of human food products and markets
3. silage
4. anaerobic digestors

5. composting - primarily with peat

6. burning/destruction

- we have briefly investigated the possibility of using oil in the herring to assist in burning this waste (such a "doomsday" machine seems unfeasible)

7. improved dumping at sea

- i.e. farther out in deep water.

I shall now discuss our involvement with the fish silage option, which has also been our primary area of work. When I consider the history of silage development in Canada, the following statement by a Japanese industrialist seems so relevant to this field, as well as many others: *"Canada is the land of the future. It was in the past and it will always be".*

In this context, just note that silage has been studied for over thirty years by a variety of government organizations and laboratories in Canada without any significant commercial production having been started. How do we stop just studying this subject and begin actually doing something?

I believe the key to achieving such a meaningful development is to convince or excite private companies about making and marketing such products. In this regard, I wish to acknowledge Joe Casey (Casey Fisheries Ltd.) and Brian Ives (I.M.A. Aquatic Farming Ltd.) as the two ardent promoters of fish silage in the Nova Scotia fishing industry. Our strategy in promoting silage production has therefore been:

1. to encourage private sector involvement,
2. to assist in developing a market demand for silage.

In dealing with the private sector, we could have focused on either:

- a) high or sophisticated technology
 - as is used in Scandinavia to produce the

consistent product needed for aquaculture, as an example, or

- b) relatively low or intermediate technology
 - which may be more appropriate for the many small or medium sized fish processing plants which may desire to utilize their wastes.

We have tended to favour and focus on the latter approach. One reason for this is that the larger fish processing companies already have fish meal plants for dealing with their wastes. Indications are that such larger companies would prefer to expand such fish meal facilities, or to construct new ones, since a market already exists for meal and oil. The major problem in the case of the herring carcasses is that it is marginal or difficult to justify such capital investments for just a 6 weeks' to 2 months' operating season.

Silage therefore appears to be an alternative which might be considered by the more than 200 small and medium sized plants spread across this province. We are also recommending that initial trials and production should utilize low fat species such as groundfish (cod, haddock, etc.) wastes, since many silage uses such as animal feeds and fertilizers require a relatively low oil content (usually less than 2%). The removal of oil from silage made from fatty species such as herring seems to be one of the most technically challenging aspects of this process, which we are trying to avoid during this initial development phase.

Even if we gain the enthusiasm of the fishing industry, however, there is still the problem that no significant market presently exists for silage in this area. The development of a MARKET DEMAND for silage has therefore been a priority in recent years.

- either in the agricultural sector, both for animal feed and plant fertilizer,
- in the finfish aquaculture, if and when this sector grows to a size offering a significant market potential.

I personally expect that in the agricultural sector, the use of silage for animal feed may remain marginal for some time because of the relatively low prices for feed grains. I suspect that the greatest short term market potential for silage may be in the organic fertilizer field, particularly for household uses. In such applications, pure economics becomes less a factor than in agricultural applications. It is interesting to note that a majority of the commercial producers of silage in the United States have focused on this particular organic fertilizer market.

With this background, I would like to outline briefly the types of silage projects with which our Department has

been involved in the past several years, either through the provision of financial or technical assistance, or both. The key staff member in most of these projects has been Mike Drebot, and he will provide later, more details on a few of these projects.

1. PILOT SCALE, INEXPENSIVE SILAGE PLANT

- With Casey Fisheries Limited.
- This pilot plant has provided silage for most of the agricultural trials conducted in Nova Scotia and Prince Edward Island in recent years.
- It will be upgraded this year, particularly to increase the storage capacity.

2. VEGETABLE FERTILIZER TRAILS

- With Agriculture Canada experimental station, Kentville. As well, the Agricultural Engineering Department of the Technical University of Nova Scotia, with funding from this Department, has designed and built a silage sprayer for commercial vegetable crops, which is presently being tested.
- As previously mentioned, given the relatively unsophisticated silage which will be produced here in the short term, I foresee organic fertilizers as offering the best market opportunity during the next few years unless aquaculture production really "takes off".

3. ANIMAL FEEDS

- Most work by Agriculture Canada has been on pigs.
- We have encouraged and have offered financial support to extend such trials to cattle and mink.

4. WATER AND OIL REMOVAL FROM SILAGE

- We have funded developmental work at Technical University of Nova Scotia.
- Removing oil from herring or herring silage is essential if it is to be used for either animal feeds or fertilizer.

5. AQUACULTURE FEED

- This Department and the National Research Council are providing financial support for a development project in this area being undertaken by I.M.A. Aquatic Farming Ltd.()

FISH SILAGE REPORT

Mike Drebot
Supervisor, Product and Process Development
Nova Scotia Department of Fisheries
Halifax
Nova Scotia

Silage has received growing priority within the Nova Scotia Department of Fisheries with efforts directed primarily to the following areas:

1. Evaluate the practicalities of silage production in light of the mounting disposal problems encountered by the small and medium sized fish processor.
2. Demonstrate the technical processes involved with small scale plant projects. These demos would involve plant personnel and provide instruction and awareness regarding the more technical side of the silage production.
3. Assist in the establishment of various centers of silage production in the province thereby assuring a source of product. Silage would then be available for trials in various areas having economic potential. Testing would center on animal feeds for ruminants (beef) and non ruminants (hog); fish feeds (aquaculture) and agriculture fertilizer (soil and tree crops).

As most participation, whether it be technical transfer, innovation or practical R & D, occurs at the plant site, the Department was quite fortunate to have the cooperation of Casey Fisheries Ltd at Victoria Beach and in particular Mr. Joe Casey who has always shown a keen interest in new technical processes.

PROJECT 1

Casey Sea Foods Silage Unit

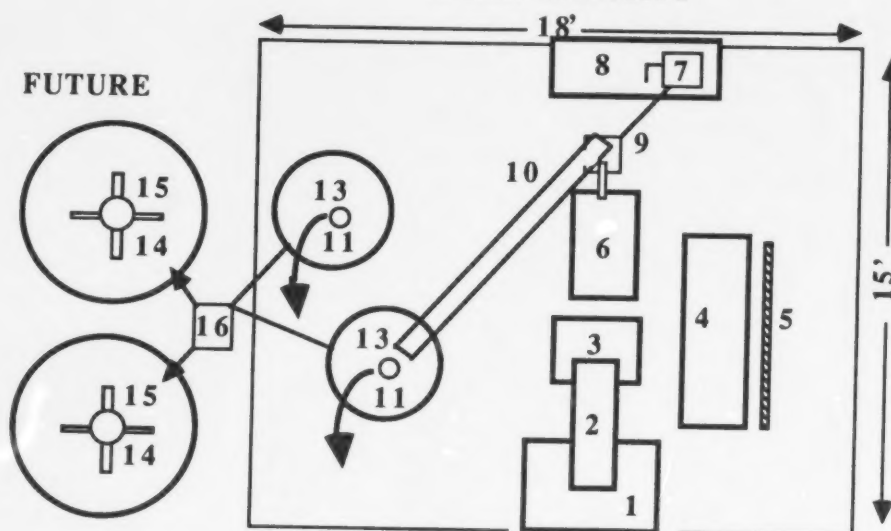
Figure 1 (next page) shows the layout of the silage line at Victoria Beach with equipment numbered in sequence. Equipment and associated costs for this pilot scale installation were kept to a minimum.

Explanation of Equipment and Costs

One of the main features of this silage process is the system of interlocks which enable one man to feed, control and operate the line. The fish is delivered to a waste fish box (1000 lb capacity) in which a draw off inclined conveyor is situated by which the fish is transported to the supply table. The operator feeds the 6" diameter grinder connected to a discharge chute where a spray head from the formic pump line is situated. This premix material is taken by a 4" grain auger and efficiently mixed during its 10 ft. travel to the primary digester and mixing tank. To scale down costs, a 4" auger (4 ft. length) was again used to mix and circulate the slurry. The two primary tanks each have a 2 ton capacity, with the mixers controlled by a 24 hour - 3 position timer. During the first 2 days, the mixers are active approximately fifty percent of the time. During the third and fourth days agitation is required twenty-five percent of the time with the remaining cycle being exposed to a 10% mix time. As stated, the essential process steps in the production cycle operate under an interlock sequence. This produces a uniform output, good pH control (acid/material balance) and allows the operator to control the unit from one position. This position is at the working platform adjacent to and within easy access of the control panels (manual and interlock switches). The grinder employed is a 6" inset grinder which when under a full load produces at a rate of 2.5 tons per hour. This size was found to be ample for all haddock and much of the cod processed at Victoria Beach. Large heads and frames from the latter species did cause some blockage and bone build-up in the cutting barrel. The formic pump has an output setting of 0-10 and this was test run at different speeds to produce an output guide to match grinder output. Over an eight hour operating period, it was found that the addition of 3.5% formic acid by weight resulted in a final pH of approximately 4.0 ± 0.1 . The pH of the silage was always kept well below 4.5 to negate any risk of

Figure 1.

FISH SILAGE FLOW SHEET VICTORIA BEACH 2 TON CAPACITY



EQUIPMENT

VALUE

1.	Fibreglass 4' x 4' x 4' waste fish tub	\$200
2.	Take-away feed conveyor	500
	8' (used) - 2HP	300
3.	Supply & surge table (wood)	200
4.	Working platform (wood)	300
5.	Equipment control panel with interlocks (wiring)	1500
6.	Rebuilt 6" meat grinder	7500
7.	Meter acid pump (diaphragm)	500
8.	Formic acid supply vessel	
9.	Acid feed tube	
10.	4" convey auger (10') - 1HP	400
(2)	11. 4" mixing auger (4') - 1HP	600
(2)	12. 2" discharge spout with hose	200
(2)	13. Fiberglass digester tank (500 gal.)	1000
	TOTAL	\$13200

FUTURE ADDITIONS

14.	2 - 8000 gal. storage	12000
15.	2 8" mixing augers	1500
16.	Silage filling and transfer pump (piping)	4500
	TOTAL	\$18000
	GRAND TOTAL	\$31000

Figure 2

**PRODUCT COSTS
SILAGE PRODUCTION 2 TONS/HR.
YEARLY DIVISOR - 3000 TONS/YR.**

Direct Costs	
Acid (Formic - 3.5% by wt.) x 60¢/lb.	\$42.00
1 Labourer \$8.00/hr.	4.00
Power (12 HP - 1000 KWH/month)	.50
Maintenance & Misc.	.50
Fish Material - (Waste at 0\$/lb)	0.00
TOTAL	\$47.00
Equipment Investment (\$31,000)	
Write-off 10 yrs. at 10% = $\frac{3100 + 3100}{3000}$	2.10
	49.10
Profit & Overhead (20%)	<u>9.82</u>
	\$58.92/ton
(40,000 lbs and up Bulk) - 1 1/2 ¢/lb. (within 100 m radius)	<u>\$30.00/ton</u>
DELIVERED - TOTAL	\$88.92/ton

botulism toxin occurring.

Having two intermediate storage tanks gives the option and flexibility to store low fat (groundfish) or high fat (herring) silage separately. Figure 1 also shows a future addition of larger tanks to store more specialized types silage (i.e. animal, fish, fertilizer grades as well as bone in or bone out silage fractions, etc.) in commercial quantities.

Cost Estimates for Silage Product

Cost calculations are shown in Figure 2. Calculated using the equipment installed at Victoria Beach; adding formic acid at 3.5% while anticipating a yearly production of 3000 tons (2 tons/hr x 8 hr x 200 days) the cost of the product (14% protein) varies between 30-35 ¢/lb. This cost may be further reduced by 10¢ depending on raw material costs and the level of Government assistance.

It should be noted that the value of the acid in terms of direct costs amounts to approximately 75% of those costs. The use of dual organic and inorganic acids (formic/sulphuric) could lower this expenditure by 20% over the "all formic mix".

Indirect costs are not affected by capital assistance or processing grants, such grants could however reduce

capital costs by as much as seventy percent. These savings would more than counterbalance the cost of an 18 ft. x 15 ft. structure which might be built to house the line. These costs are shown in Figure 2. Similarly, effective production scheduling utilizing low energy demand periods such as between 10 p.m. and 6 a.m. could bring significant savings in power costs.

Referring again to Figure 2, an F.O.B. value of 30-35 ¢/lb. for silage containing 14% protein and approx. 80% water is found. These costs are meaningful, however the dilemma of transporting product with such a high water content from plant to a user's site must be resolved.

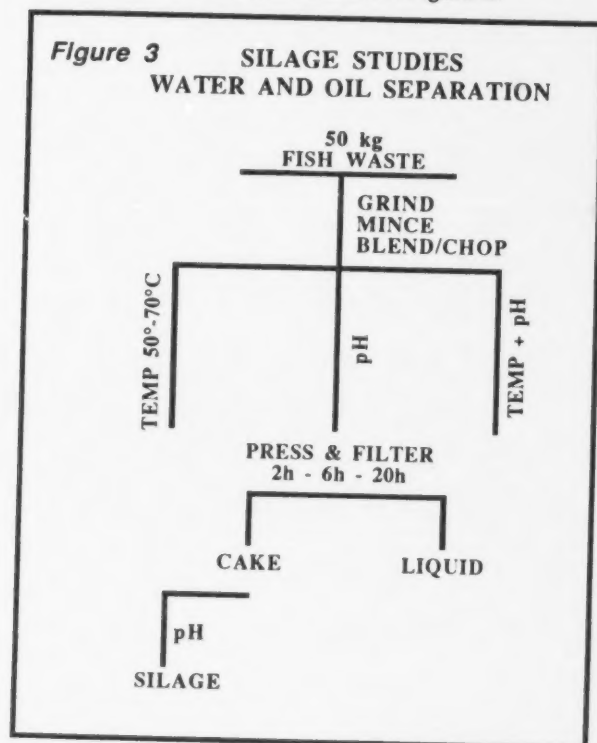
Taking a working example of plant to farm transport (within 100 miles) of liquid silage, the most economical rates (bulk rates for 40,000 lbs or more) would be 1.5¢/ton/mile. This raises delivered costs by another \$30/ton to a total of \$90/ton.

Taking in routing costs we find that the costs per pound protein in silage would amount to 33¢. The cost of soybean meal (48% protein) and fish meal (70% protein) would be 40¢ and 35¢/lb. respectively.

PROJECT II

Silage Studies - Water and Oil Separation

Research was carried out by the Canadian Institute of Fisheries Technology at the Technical University of Nova Scotia under the direction of Professor John Merritt and was funded by the Nova Scotia Department of Fisheries. The work is outlined in Figure 3.



Project objectives were: 1. to determine a practical and economical oil removal method for the "intermediate stages" of silage produced from herring with a fat content of 12% or more; 2. to concentrate, prior to final silage hydrolysis, fish solids through effective water reduction in the starting materials. Successful results would enable herring carcasses from roe operations to become feasible raw material for animal silage feeds while upgrading the protein levels (through water removal) of ground fish silage which would enhance this product in the present group of conventional dry feeds.

As shown in Figure 3, the starting materials were subjected to various physical and chemical treatments, temperatures (50°-70°C) process cycles (2; 6; 20 hours) and pH factors to determine the most effective method for water and oil separation. Water release aided by mechanical tissue rupture versus tissue

denaturation through acid and temperature effects were evaluated.

Chemical analyses were also structured to determine gain and losses (N, H₂O, oil) in the various steps. Stability trials regarding free fatty acids as well as the C22 polyunsaturates, which have been implicated in the formation of fishy flavours in pork, were carried out.

Analysis of the data from these experiments is in progress with results indicating that certain strategies have encouraging possibilities.

PROJECT III

Silage Fertilizers

A cooperative program initiated by the Nova Scotia Department of Fisheries and the Kentville Research branch of Agriculture Canada to evaluate various fish silages as crop fertilizers began in 1983 and has continued to the present. All silages used have been produced from fish waste or materials presently classified as discard. Plant growth trials and evaluations were supervised by Dr. Roger Blatt of Agriculture Canada. Growth sites were in the Kentville/Valley area which has loamy sand soil characterized by low OM, low nutrient exchange capacity and low water retention capabilities. Special emphasis was given to heavy users of nitrogen which included the commercially important Cole family of cabbage, cauliflower and broccoli.

Table I (next page) shows analyses of various fish-shellfish silages produced during the '82-'86 period. It should be noted that the composition will vary depending on the raw material. Common example differences being lean or fat fish; gutted fish or ungutted fish or fish frames from manual or machine filleting. It can be seen that dry silage which has been concentrated has the highest nutrient values (around 10% N) compared to the natural liquid type of around 3%. The "dry" form is also quite attractive in terms of transportation costs compared to liquid products which contain up to 80% moisture. The negative feature is, of course, the energy costs that go into moisture reduction to produce a stable commodity (8-12%). Crab fertilizer used was produced in 1976 from wastes obtained from cooked rock crab processing. The product was dried (180° - 200° F) to under 10% H₂O and then hammermilled to produce a free flowing gritty product. All silages were treated with the anti-oxidant ethoxyquin at levels of 200 to 400 ppm.

SILAGE AS FERTILIZER
Approximate Analysis of Fish Fertilizers
used from 1982 to 1986 in Field Growth Tests
by Agriculture Canada, Kentville

TABLE I	%								PPM				
	FAT	H ₂ O	N	P	K	Ca	Mg		Fe	Mn	Cu	Zn	B
Dried Cod Silage	1.2	10.2	9.9	4.5	1.0	5.5	0.2		59	10	3	52	2
Liquid Cod Silage	2.4	74.4	2.9	0.2	0.5	0.1	-		18	3	.8	20	2
Crab	0.9	8.5	3.5	1.5	0.2	16.6	1.0		193	240	37	85	14
Fish Bone Meal	1.8	7.2	5.9	10.1	0.1	19.4			1120	42	26	107	23
4:1 Cod/Crab	0.8	9.7	8.3	4.8	0.8	8.8	0.4		115	64	12	59	4

1983 - YIELD TEST (MARKETABLE)
Using Dried Silage and 17-17-17 Commercial

Fertilizer Treatment	N (kg/ha)	YIELD(gm/plant)		
		Broccoli	Cabbage	Cauliflower
1. 17-17-17	150	637	1305	717
2. COD	75	398	1149	617
3. COD	150	501	1298	830
4. COD & CRABMEAL	150	555	1207	842

1984 - YIELD TESTS (MARKETABLE)
Effect of 17-17-17 and Dried Fish Silage Supplied at 150 Kg N/ha on Yields of Six Vegetables

Crop	YIELD/PLOT (gm)		Wt/HEAD (gm)		DIAMETER (cm)	
	17-17-17	fish silage	17-17-17	fish silage	17-17-17	fish silage
Seeded						
Beans	3944	3200				
Carrots	9489	7173				
Peas	394	162				
Transplanted						
Broccoli			398	440	15.9	17.2
Cauliflower			422	280	10.4	9.1
Lettuce			515	552	11.1	11.0

Table II (1983)

Figures were obtained during harvesting with the plants dressed and prepared in marketable forms prior to weighing. Data shows all vegetables responded effectively to the silages used compared to the commercial triple 17 (N-17; P-17; K-17). All treatments were added in the dry state (Preplant) at rates from 75 -

150 kilograms per hectare (kg/ha). Cauliflower exposed to dry cod silage and a mixture of 4 parts cod silage and one part crab meal outproduced the triple 17 by approximately 17%.

Table III (1984)

The 1984 experiments were essentially the same as

1985 - MARKETABLE YIELDS
From 17-17-17 and Fish Silage (dried)

TABLE IV

Crop	Application Method		gm/plant	17-17-17	Source
	Single 150N	Split (Side dress) 100N 50N			
Broccoli	516	543		546	Dried fish silage 513
Brussels Sprouts	482	451		**536	396
Cabbage	1671	1652		1677	1646
Cauliflower	794	701		773	722

** Significant difference

1986 - YIELD TESTS
Yield Tests Using Commercial 17-17-17 with Fish Silage Products

TABLE V

Treatment	Fertilizer	Rate of "N" & Method of Application
#1	17-17-17	150 Kg / ha - Preplant
#2	Pelleted Fish Silage	150 Kg / ha - Preplant
*#3	Liquid Fish Silage	100 Kg / ha - Preplant
#4	Fish Bone Meal	50 Kg / ha - Side dress
*lowest rate		

MARKETABLE YIELD (gm/plant)

Treatment	Broccoli	Brussels Sprouts	Cabbage	Cauliflower
#1	335	308	1441	345
#2	285	238	1412	374
#3	245	173	1084	288
#4	261	184	1216	227

those in 1983 but crops were grown at a different site (Kentville vs. Berwick) to determine if reproductability could be obtained for Cole crops grown from transplants. Some vegetables planted from seeds were also evaluated. All fertilizers were applied preplant at one rate (150 kg/ha). From Table III it can be seen that with silage, cauliflower was down significantly while broccoli outproduced its counterpart (+ 10%) with head lettuce showing a 10% gain as well. Diameter of marketable heads showed similar trends. The triple 17 tended to favour the seeded crops over the silage.

Table IV (1985)

Tests were conducted at the same growth site as those in 1984 with emphasis again on the Cole crops. The fish silage however was used in a compacted pellet form rather than the fine irregular sized particle form. The pellet type produced better control and more efficient application procedures. Both fertilizers (triple 17 and pellet cod silage) were tested as a single preplant (150 kg/ha) as well as with an initial preplant rate of 100 kg/ha (N) followed by a 50 kg/ha (N) 4-6 weeks after planting (transplants). Table IV shows no significant difference between application methods. Therefore one single preplant would be most

advantageous and economical.

Broccoli, cabbage and cauliflower showed no significant difference between the two types of fertilizers. Brussel sprouts however showed significant less yield with silage (down over 20% compared to triple 17).

Table V (1986)

This experiment was conducted for the third straight season on loamy sandy soil (Somerset type). Silages included the previous pellet type plus 2 new forms: A. natural liquid cod fish silage; and B. dried fish bone meal made from washed, dried and pulverized salt fish frames. All, including triple 17, were applied to the transplants (Cole crops) in various rates and applications (Single preplant or single plus side dress). Nitrogen again was added to produce a total of 150 kg/ha.

The pellet fish silage contains approximately 10% N. the liquid silage about 3% N. (30 lb. in 100 gallons of liquid) and the dried fish bone meal approximately 6% N.

Production yields show brussel sprouts repeating its choice for the triple 17 while cauliflower and cabbage showed good performance with silage pellets and equal to the triple 17.

Liquid fish silage showed encouraging results when application rates are compared. (dosage rate was 1/3 less the others). The function of fish bone meal, although showing respectable results, might exist as a supplement to fish silage to increase its "P" content

and for producing a more balanced fertilizer in soils low in P and K.

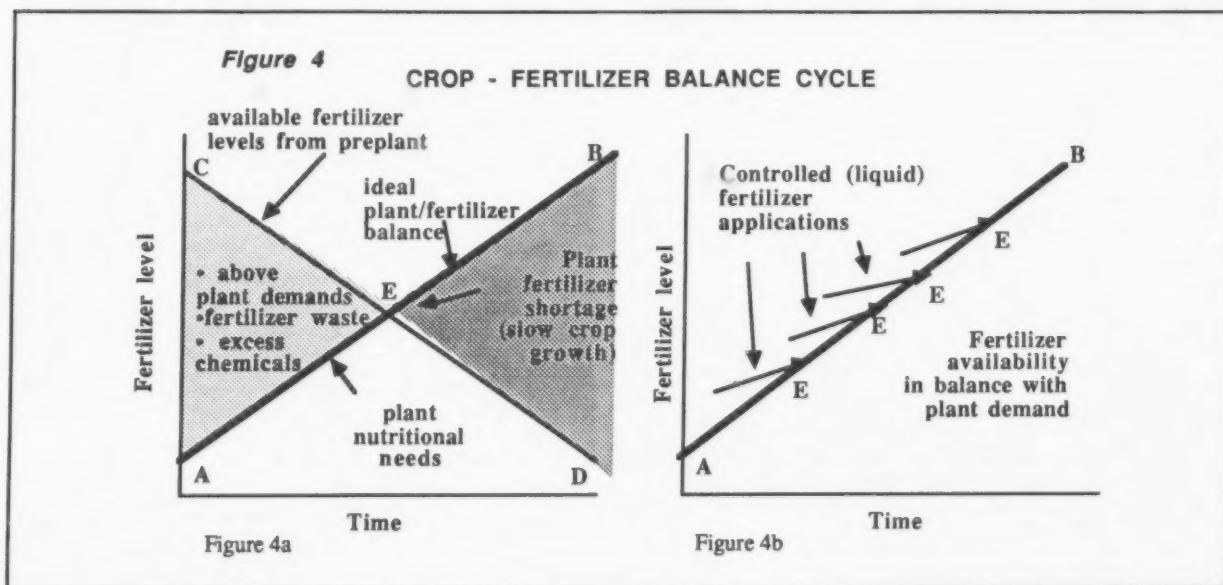
PROJECT IV

Foliage Spray

Recent work with foliage spraying has shown this method, in many cases, to be highly productive compared to root intake. Preplant or in ground dosage may see up to 70% of the fertilizer lost due to leaching, poor position and distribution, varying plant demand rate and other physical/biological factors. Tracer tests done by the U.S. Atomic Energy Commission have shown very efficient absorption of liquid silage through leaf systems compared to the conventional passage via root systems. More efficient use of nutrients occurs as liquid feeding produces more control preventing overuse of costly fertilizers. Figure 4(a) demonstrates what can happen with traditional fertilization. Initial concentrations far exceed plant demand and can produce chemical intoxication and excess salts in the soil.

As the plant growth continues along AB, the initial concentration of fertilizer declines to ED. At the mid point there is nutrient balance between plant need and fertilizing availability, however decline/growth occurs along line ED unless additional fertilizer demand is met.

In the second curve, 4(b), there are similar initial conditions as those of the first. However, maximum growth and the most efficient use of nutrients is



obtained by adding low strength liquid fertilizer in controlled amounts. Dosage is applied at various time intervals to coincide with maximum plant balance demand shown along the diagonal AB. Work in this area will be continued during 1987.

Liquid Dispensing Systems

It becomes obvious that with liquid rates in the mini or micro range (10 gal/acre), silage must exist in a state free of any solids that would critically interfere with the delivery circuitry (pump; feed lines; spray heads, etc.). As fish silage can contain as much as 20% bone, it becomes essential that a free flowing non gritty state is produced. With Dr. Blatt's proposed time table (May trials) the Department funded a design project with T.U.N.S. to develop a spray system that would efficiently accommodate fish silage containing solids up to 20 mesh size. Development was directed by Dr. Chris Watts, head of the Agricultural Engineering section at the university.

A variety of test materials were produced from the Casey plant and delivered to T.U.N.S. for evaluation. It became apparent that process alterations would be necessary to permit maximum use of the Victoria Beach product.

A completely homogenous, solid free product was produced from 1.2 mm pressured strainer accounting for 80-90% of the initial starting materials.

With significant phosphorous content, attempts were made to recover the bone grit fraction and utilize it separately or integrated (after physical modification) with the strained liquid fraction.

Phosphoric acid (also a source of P) and sulphuric acid were used to promote bone decomposition. A 3% addition of H_3PO_4 gives the silage an elemental rating of 3% N - 1.5% P - 0.5% K.

CONCLUSION

Reviewing the silage work from 1983 to the present, initial objectives have generally been met. A small pilot plant producing silage has been established. Equipped and modified at minimum costs, the Victoria Beach operations have produced in excess of 100 tons over the last 4 years. The unit has been the source of virtually all the product used for experiment and evaluation trials (Kentville Agric. - Canada 1983-87). In addition, future allocations for beef and fur bearing (mink and fox) types have been committed. Fertilizer evaluations will also be expanded to gauge growth response (foliage spray) on orchard and woodlot operations. The latter would include the high profile Christmas tree industry. Experiments will also be carried out on holding raw material prior to processing. ◊

FISH SILAGE EVALUATION FOR SALMONID DIETS

Dr. R.H. Cook
Biological Station
Department of Fisheries
and Oceans
St Andrew's, N.B.
E0G 2X0

Dr. C Frantsi
Connors Bros Ltd.
Black's Harbour
N.B.
E0G 1H0

The Salmonid Demonstration and Development Farm (SDDF) was established in 1985 in Lime Kiln Bay, New Brunswick, under the Canada-New Brunswick ERDA on Fisheries. The Farm consists of a shore-based office/laboratory building and a sea-cage site where salmonids may be subjected to various performance trials to evaluate such factors as diet formulations, husbandry measures, genetics and selection.

The SDDF program is guided by an Advisory Committee comprising the Federal and Provincial fisheries departments and the aquaculture industry. It has been agreed that the primary focus of the SDDF program would be on nutrition and feed performance. The use of fish silage as a base for salmonid diets was identified by the Advisory Committee as an issue the Farm should address. Accordingly, a cooperative project was developed with Connors Bros. Ltd, Aquaculture Division and the SDDF with financial and technical support provided by the Development and Biological Sciences Branches of the Scotia-Fundy Region, Department of Fisheries and Oceans.

There are three basic facets to this project:

1. the construction of a pilot scale fish silage production unit and the production of silage-based diets including the evaluation of ingredient mixes required for proper pellet formation and the formulation of a suitable diet;
2. the evaluation of storage capabilities and nutritional aspects of the silage-based diets;
3. the conduct of performance trials of silage-based diets, in comparison with other moist and commercial dry feed formulations, on smolts at sea-cage sites over essentially an 18-month period. The evaluation of these fish would cover the growth rates and feed efficiencies over this experimental period.

The sea-cage trials would be located at the SDDF in Lime Kiln Bay and at the Connors Bros. Ltd Marine Operation site in Fairhaven, Deer Island and possibly other farms willing to participate in the experiment. The collection of data at the cage sites would include growth, feed efficiency, survival, body composition changes or effects, as well as general observations on fish health and condition. The costs of fish silage production and the evaluation of fish silage as an appropriate method for producing feeds to support the Bay of Fundy salmonid aquaculture industry will also be evaluated.

The silage production unit will consist of acid resistant silage bins, fish grinder, acid proportioning pump, a sewage-type pump for moving the material from the bins, a stirring apparatus which would be a large propeller with a low ratio gear-driven motor, pH control unit or evaluation equivalent. Most of the equipment required for the silage production unit will be provided by Connors Bros. Ltd.

Whole herring carcasses, herring roe carcass and herring cuttings will be used for this investigation. Formic acid will be the acid of choice in this work. The choice of formic acid is based on the work of Lall et al., 1986, who observed that formic acid-preserved silage resists microbial deterioration, liquifies rapidly and does not require neutralization before feeding if an appropriate binder meal is used. The ensilaging procedure would involve particle size reduction of fish by grinding and further combining of ground material with 85% formic acid in the proportion of 3% by weight of raw fish. The whole, fresh herring carcasses will be ground and transferred to silage bins where an acid proportioning pump would gradually pump formic acid directly into the fish. The silage bins will be made from material with non-corrosive contact surfaces and fed in with a motor-driven agitating paddle or possible sewage pump to insure thorough mixing and homogeneity of the acidified fish waste. This pump

would also be used for the stirring of the mixture during the digestion process. The silage will be established with 250 parts per million of the anti-oxidant ethoxyquin (Monsanto, M.O., U.S.A.) to prevent the oxidation of lipid. The pH, lipid quality (peroxide value, thiobarbituric acid value, free fatty acid) and moisture content of silage will be monitored periodically. Material may take 4-7 days for complete digestion.

The diet preparation will consist of a dry portion of the diet (55%) and (45%) silage. If there is a problem with excessive moisture in silage, this dry mix proportion and silage may require a slight modification. The mixed diet will be extruded to obtain a desired size pellet for feeding. The food production will be essentially for daily use although shelf-life studies will be conducted on this feed.

Feeding trials will be conducted using silage-based diets and compared with commercial moist and dry

feeds as controls. The moisture composition of the moist diet is essentially the same as a silage diet, where silage replaces ground herring in the diet. The duration of the experiment will be 18 months, commencing in July, 1987. Each of these diets will be fed to Atlantic salmon smolt held in cages at densities of 2500-5000, 2500 at the SDDF facility, and up to 5000 at the Connors' Fairhaven Marine Operation. These diets will be fed on an *ad-libitum* basis. Detailed records of feed consumption, growth and mortality will be maintained. The response criteria includes growth rates, feed conversions, fish survival and body composition and gross nutritional pathology.

The information obtained by these studies will be made available to all interested parties. The experimental findings will be published as a technical report.◊

SILAGE TRIAL

John L'Aventure
President, Fundy Aquaculture Ltd.
Seal Cove, Grand Manan
New Brunswick
E0G 3B0

A fish silage fish food project was carried out by Fundy Aquaculture Limited at their salmon farm on Grand Manan. This was done with the financial assistance of N.R.C. and the technical assistance of Dr. Santosh Lall, D.F.O.

The purpose of this project was to test the feasibility of making a palatable moist pellet with fresh roe herring which would be acceptable to the salmon. The food conversion (pounds of gain on fish against pounds of food fed) was monitored along with the weight gain of fish on the silage diet.

A lot of 2000 salmon was split into two cages of 1,000 fish each. One cage was put on a silage diet and the other group was fed on regular moist diet. These fish were put on this trial diet January, 1986 and the trial was stopped February, 1987 when the fish were harvested. Both trial and control lots were fed at the same time, and both lots were fed to satiation.

Feed Preparation

The regular moist diet was made fresh six days a week, whereas the silage food was made up only every two

weeks and frozen because of the small consumption.

The raw material for silage were very fresh herring caught and ground up the same day. These fish (1000 pounds) were put into an Xactic container and then 3% by weight of formic acid was added, which lowered the pH to 3.8. This mixture was stirred several times a day until it became liquid, and the acid was well mixed. In a later batch it wasn't mixed as well and the whole batch went bad. The fresh ground herring were high in moisture (79%), so the final diet had more middlings than usual. The final diet using ensilage fish was 40% ensilage, 33% fish meal, 19% wheat middlings, 6% fish oil and 2% vitamins and minerals. In later batches sulphuric acid replaced some of the formic acid. The equipment required was a mincer, a 1000 pound tank, and a paddle to stir with. A face mask and rubber clothing was worn by the stirrer for protection against the acid. The final pellet had a better consistency than the regular moist pellet and there were almost no fines, with the pellet staying together better when thrown in the water.

The feeding trials lasted 13 months and the fish were harvested in February, 1987. (Appendix A and B).

Appendix A

	Silage diet	Regular moist diet
Cage Number	47 A	47 B
Number of fish at start	1000	1000
Number of fish harvested above 4 pounds	697	666
Number of fish under 4 pounds	219	224
Mortalities	87	91
Average gutted weight of fish harvested	5.7	6.15
Food conversion rate	2.7	2.1

Appendix B

Amount of Feed Fed Kilograms

Date	kilograms of silage food	kilograms of of regular food
March 1986	60.00	51.6
April 1986	70.37	101.66
May 1986	204.18	156.88
June 1986	296.42	323.90
July 1986	427.93	375.17
August 1986	503.73	518.44
September 1986	446.78	484.08
October 1986	829.27	758.07
November 1986	717.26	561.26
December 1986	329.77	304.01
January 1987	297.90	315.0
February 1987	130.29	117.59
Food Conversion	2.70	2.12
Sampled weight December 2/86	1.83	2.16

This silage was frozen and then fed so it developed more fines. It also sank faster. These factors may have altered the food conversion ratio.

Conclusion

The mortality rates were similar and the rate of small fish under 4 pounds were similar. The fish did grow slightly larger (7%), on the regular moist diet.

A PROJECT WITH FISH SILAGE AS HOG FEED ON PRINCE EDWARD ISLAND

Dominic Johnson
Livestock Nutritionist
P.E.I. Hog Commodity Marketing Board
Charlottetown, Prince Edward Island
COA 2H0

Work with fish silage was undertaken on Prince Edward Island in the late 1970's. It was established that fish silage could be fed successfully to a number of types of livestock. However, the utilization of fish silage as a livestock feed has not occurred. This is considered partly associated with the non-availability of a practical method to feed fish silage.

This project titled "Non-Traditional Feeds for Hogs" was initiated by the P.E.I. Hog Commodity Marketing Board in the Spring of 1986. Fish silage is one of the non-traditional feeds under evaluation.

There are 2 parts of the project regarding fish silage:

A) The setting up of a pilot plant to produce fish silage. The purpose of the plant is to allow familiarization with fish silage production and to establish cost of production of fish silage.

B) The installation on a hog farm of a computerized liquid feeding system. This system allows for the mixing of liquid hog diets and their distribution automatically to hogs in pens. Diets with prescribed levels of ingredients are entered into the computer. The next step is to enter into the computer the number of hogs in a pen and their weight. The computer then calculates, based on nutrient requirements, the amount of feed to deliver to each pen and keeps a daily record of the amount delivered.

Fish silage produced is delivered to the farm where a 10,000 gallon concrete storage tank is in place to hold sufficient silage for the winter months. Before diets containing fish silage are prepared, the computer activates a motor in the storage tank to agitate the fish silage.

The feeding regime with fish silage is 10% fish silage in starter diets (20 to 50 kgs); 5% in grower diets (50 to 70 kgs) and 1% in finisher diets (70 kgs to market). Records of average daily gain, feed consumption, feed efficiency and slaughterhouse indices are collected on test groups of hogs.

In addition to assessing fish silage, this project is attempting to assess the efficiency of the liquid feeding systems. Therefore data is collected as follows:

- A. Traditional Dry Feed Diets.
- B. Traditional Dry Feed Diet Fed Via the Liquid Feed System.
- C. Fish Silage Diets Fed Via the Liquid Feeding System.

Comparisons and economic assessments of the diets will be completed in the late Fall of 1987.

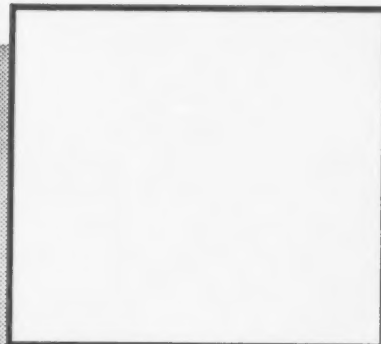
At this stage in our project it is difficult to predict the future of fish silage in the hog industry. There are two major concerns. One is whether fish silage can be produced economically. Fish silage must compete in a market place with fish meal at \$500 per metric tonne and barley at \$100 per metric tonne. When compared to these prices fish silage is calculated to be worth about \$100 per metric tonne.

The second concern is regarding the feeding of fish silage on farms. In order to feed fish silage practically, liquid feeding systems are necessary. These feeding systems require substantial investments which cannot be justified for the purpose of feeding fish silage, particularly when production cost of fish silage is marginally competitive with other feeds. However, an investment in feeding systems may be justified if other low-cost by-products are available in addition to fish silage.

In our situation on Prince Edward Island, an agricultural industry exists in close proximity to the fishing industry that could serve as a market for fish silage. There is a need for hands-on experience in feeding the product to different classes of livestock to familiarize farmers with the feed. At the same time back-up professionals are needed in extension and research to ensure the silage is produced and fed according to recommended guidelines.

THE POTENTIAL FOR FISH SILAGE

Andrée Gendron, Pierre Bryl and Françoise Nicol
Department of Agriculture, Fisheries and Food
Ocean Fisheries Division
Scientific and Technical Research Directorate
96, Montée Sandy Beach, P.O. Box 1070
Gaspé, P.Q. GOC 1R0



INTRODUCTION

This presentation is a brief outline of the current situation in Quebec with regards to the ensiling of fish wastes, based on studies conducted by the Scientific and Technical Research Directorate of the Department of Agriculture, Fisheries, and Food. It will include a study of the fish waste problem conducted by Mr. André Martin in 1985, and a summary of the research conducted by Mr. Guy Auclair in 1985-86. The presentation will also include a review of proposed future research activities prepared by Mr. Pierre Bryl, who is currently responsible for all work dealing with fish wastes at the S.T.R.D.

We will first of all give a general overview of the fish wastes problem here in Quebec. This starting point has been chosen because the problem of fish wastes is the impetus behind our decision to examine the possibility of producing fish silage in Quebec. Secondly, we will describe briefly the fish silage research projects carried out by the S.T.R.D. These deal primarily with lactic acid fermentation, and with a proposed feasibility study on fish silage production. Finally, we will share with you our proposals for future research activities. These will include obtaining a better knowledge of the composition of our total fish wastes, the methods of preserving these, and the various ensiling processes which are deemed suitable for its end-use and its economic vitality.

1. AN OVERVIEW OF THE FISH WASTES PROBLEM IN QUEBEC IN 1985

1.1 Volume and distribution of wastes

The Quebec fish processing industry produces an annual volume of approximately 30,000 tonnes of fish wastes, or by-products. Three zones have been

identified as the principal areas of accumulation. These areas are the Gaspé region, the North Shore (of the St. Lawrence) and the Magdalen Islands. The volume of fish wastes is 20,000 tonnes in the Gaspé region, 4,000 tonnes in the North Shore area, and 8,000 tonnes in the Magdalen Islands.

1.2 Disposal sites for fish wastes

Fish plants are responsible for the management of the waste produced by their plants. Table 1, on next page, outlines the methods used by Quebec plants for the disposal of these wastes. Approximately 50% of the total is buried, either at privately or municipally-owned landfill disposal sites. There is also a limited amount of dumping at sea. The costs associated with this disposal are estimated at \$17 per tonne. Municipal and provincial regulations governing disposal on landfill sites are becoming increasingly restrictive therefore disposal of these by-products is becoming more and more of a problem for Quebec fish processors.

1.3 The extent of recovery and recycling

A portion of these fish wastes are recovered and are "recycled" by the following industries:

- mink production: as mink feed, either ground or whole, fresh or frozen
- pet food: primarily ground and frozen
- fish meal: production of protein supplements and oil
- the fishing industry: as lobster bait.

On a geographical basis, the situation can be summarized as follows:

Table 1

FISH WASTES DISPOSAL SITES IN QUEBEC, IN 1985 (Metric tonnes) ¹							
GASPÉ		NORTH SHORE		MAGDALEN ISLANDS		TOTAL - QUÉBEC	
	fish molluscs & crustaceans	fish molluscs & crustaceans	fish molluscs & crustaceans	fish molluscs & crustaceans	fish molluscs & crustaceans		
NON-RECYCLED WASTES							
Dumped at sea	-	1,141	228	-	1,400	1,141	1,228
Landfill site or dump	5,267	958	1,529	-	-	6,225	7,342
Total non-recycled	5,267	2,099	1,757	-	1,400	7,366	8,570
RECYCLED WASTES							
Ground and frozen	6,725	-	-	-	-	6,725	-
Sold as is	-	-	-	520	-	520	-
Fish meal	4,694	463	-	6,269	-	10,848	-
Total recycled	11,419	463	-	6,789	-	18,093	-
GRAND TOTAL	16,686	2,562	1,757	6,211	1,400	25,459	8,570
RECYCLING RATE (%)	68,4%	22,1%	0%	100%	0%	71,1%	0%

¹ Based on consultations and a survey conducted by the Quebec Department of the Environment in 1985.

- Fish wastes are almost completely utilized and recycled in the Magdalen Islands.

- Recovery rates are approximately 68% in the Gaspé region and 28% in the North Shore region.

- Over the entire Quebec Fisheries region, wastes from crustaceans (crab, shrimp, lobster) are not recycled.

Table 2

Census of the number of mink breeders in Quebec compiled by the DAFF

	number of breeders	number of females in production
October 1985	102	68,636
January 24th 1986	83	54,720
February 17th 1986	70	49,840

Income generated by these recycling activities was estimated at \$2.5 million in 1985, with \$1.5 million for fish meal. The cost of disposing the non-recycled portion was estimated at \$300,000.

Recycling activities are currently hampered by certain major economic problems. The Quebec mink industry, which purchases approximately 3.5 tonnes of fish wastes annually, is presently in a state of decline (Table 2). The fish meal producers must compete, pricewise, on the international protein supplement market. The Quebec fish meal plants are obsolete, and their operation is hampered by their high-cost energy requirements.

2. RESEARCH PROJECTS CARRIED OUT BY THE SCIENTIFIC AND TECHNICAL RESEARCH DIRECTORATE

Faced with this problem situation, the Scientific and Technical Research Directorate of the Quebec Department of Agriculture, Fisheries, and Food reacted by giving responsibility for fish wastes to the Fish Processing Technology Section (Figure 1, below).

We first of all proceeded to analyze in some detail the extent of the fish wastes problem in Quebec. We then focused our activities on fish silage.

Figure 1. Organizational chart

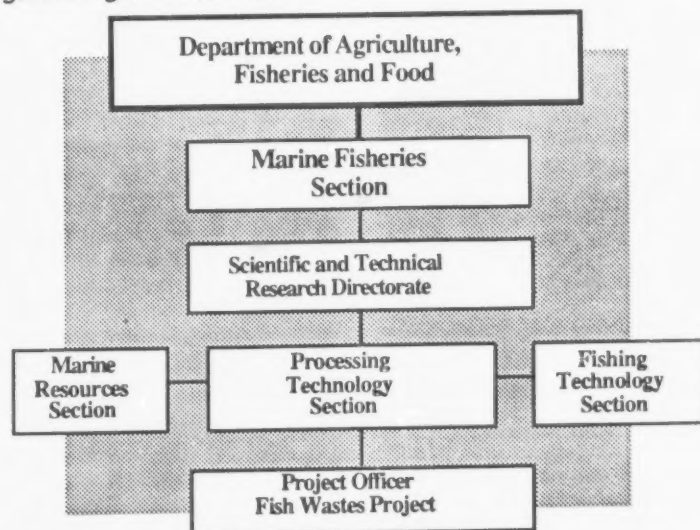
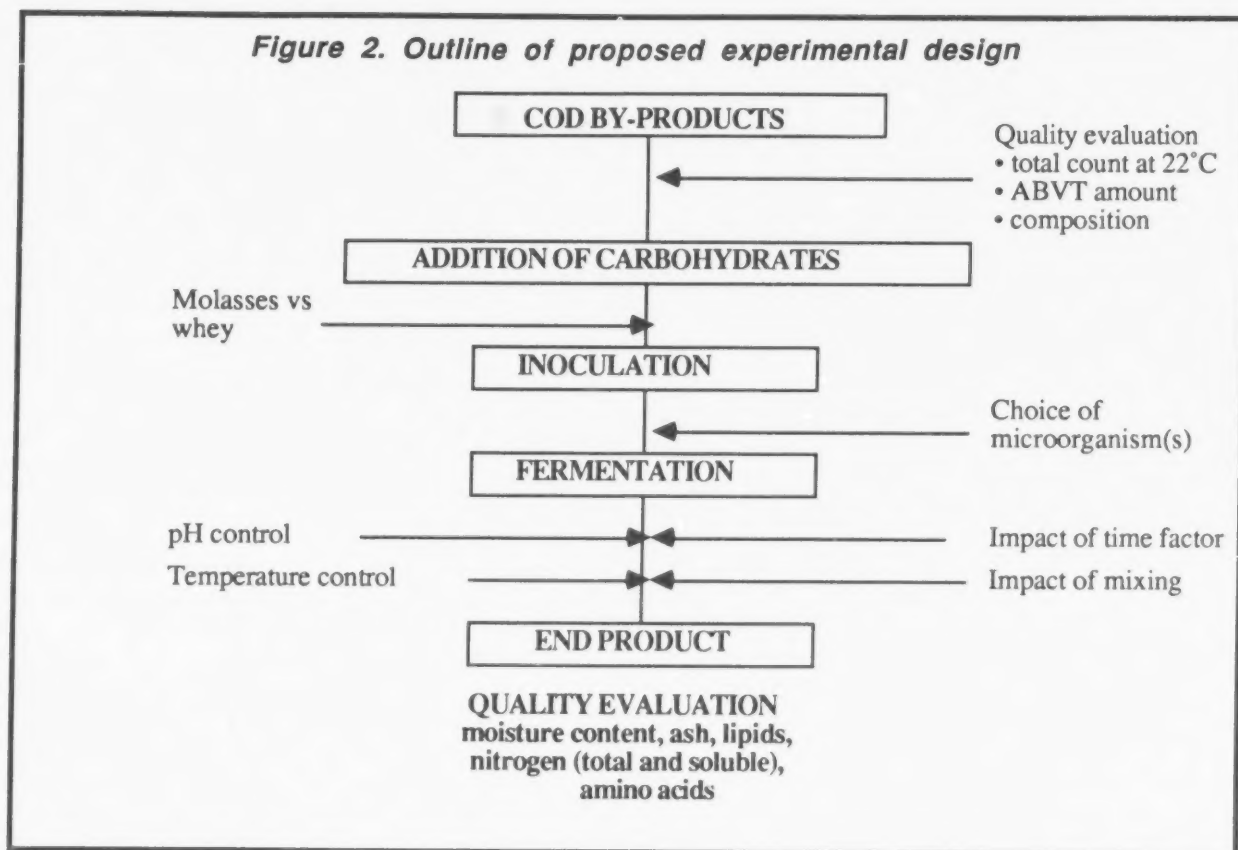


Figure 2. Outline of proposed experimental design



2.1 Preserving fish wastes by lactic acid fermentation

The first research project was carried out by Mr. Guy Auclair, of the S.T.R.D., in cooperation with Université Laval in Quebec. The research project was entitled "Preservation of Fish Wastes by Lactic Acid Fermentation". Figure 2 summarizes the experimental design for this project. The reasons which motivated the S.T.R.D. to choose this project were the low production costs associated with this bacterial technology, as well as the organoleptic and biological qualities of the end product. The results of this research project should be available by the fall of 1986.

2.2 A Study of the feasibility of fish silage production and marketing

Following the completion of the previous experiment, a study on the feasibility of producing and marketing animal feeds derived from fish wastes was jointly proposed by the S.T.R.D. and Le Centre québécois de Valorisation de la Biomasse (Quebec Centre for Biomass Protection). This study should establish clearly the conditions necessary for an economically

viable fish silage production, using either the acid or the bacterial fermentation method.

3. FUTURE FISH SILAGE RESEARCH PRIORITIES AT THE S.T.R.D.

The principles underlying the use of acids for the preservation of fish wastes are well known. In 1985, there was no expertise in this area in Quebec. The S.T.R.D. decided to expand its knowledge in this area, in order to be in a position to share this knowledge with the Quebec fish-processors.

Based on our analysis of the Quebec situation, our efforts in the area of research and development will focus on five main areas:

A) The composition of fish wastes: This will involve the identification and quantification of the various, economically significant, components of fish wastes. This information may influence the selection of methods for processing, handling, and/or preserving fish wastes.

B) Preserving the quality of fish wastes: We will identify fish wastes handling and conservation methods which will allow initial quality to be maintained.

C) Preserving fish wastes by the silage method: We will attempt to identify silage-making processes which allow optimal preservation of the desirable qualities.

D) Solubilization, separation, and concentration of the various elements: We will also determine which are the most appropriate methods for solubilizing, extracting, and concentrating some of the constituents, such as: proteins, lipids, pigments, minerals, etc.

4. THE ECONOMIC VIABILITY OF FISH SILAGE UTILIZATION

We will identify, and follow-up on, the possibilities of using fish silage as feed for various livestock: beef, pork, mink, salmonids, chicken, etc. This will be done in cooperation with the Livestock Nutrition Service of the Department of Agriculture, Fisheries, and Food.

- We will evaluate the use of fish silage as a primary constituent in the manufacture of artificial bait or fertilizer.

- We will also explore the possibility of utilizing the solid residue portion of certain silages (minerals, chitin).

CONCLUSION

The future orientation of the S.T.R.D. in the area of fish silage research is not cast in stone. The mandate of the marine fisheries section of the Department to foster the development of aquaculture could direct our efforts on the use of fish silage by this industry. Future research priorities, however, will be based on a positive economic evaluation, and will require close cooperation between research and industry. Other factors, such as regional socio-economic benefits, and the impact on the environment, will also be taken into consideration.◊

OTHER ACTIVITIES NEWFOUNDLAND

(transcription)

Winston King
Marine Institute
St John's
Newfoundland
A1C 5R3

It would seem as if I'm the only speaker today who will not be speaking from first hand experience. I have made fish silage myself but it's been strictly on a lab-scale basis. As Mr. Jangaard mentioned, we've just completed a workshop on fish meal, oil and silage which took place at the Marine Institute on April 22 and 23 of this year and we had papers there presented by Peter Jangaard and Santosh Lall. At that time I presented an overview of fish silage production in the Atlantic area and this presentation here will focus strictly on the Newfoundland scene.

I'd just like to refer, first of all, to some slides that were presented to the group this morning by Peter Jangaard giving an overview of his visit to Norway. He showed some slides outlining the production of fish silage from seal carcasses. If you can remember, he showed a four blade grinding machine and thereafter the ground material was used in regular production of fish silage. At the workshop in St. John's there was a gentleman there representing Carino, a Norwegian company which buys seal pelts in the Newfoundland area. At that time we were informed that his company was looking at the feasibility of setting up a fish silage operation in the local area. Because of adverse publicity on the international scene, the seal hunt has been at a bit of a low but in the past year Carino Co. purchased somewhere in the order of 15,000 seal pelts and also the Co-op purchased a similar number and the price at that time I heard mentioned, was somewhere in the order of 17\$ a pelt. So it would appear as if there would tend to be some revival down the road in this particular industry. Now, whether or not seal carcasses would be cheap enough to be used as raw material for conversion in fish silage is rather questionable. Newfoundlanders tend to eat a lot of seal meat and the going price for a seal carcass is somewhere in the order of around 50 cents a pound. I would think that it's rather expensive material for conversion into fish silage.

Since 1979, the Exploits Valley Development Association has been working towards the establishment of a fish silage operation in the Grand Falls area and full marks have to be given for this particular group because they have done all the spade work in putting this proposal together. In 1981, a five-man delegation travelled to Europe to view operations in Norway and Denmark and since that time a consulting firm has investigated the possibility of setting up a fish silage operation. A group was convened last fall and a representative from the association gave us an overview of what they had in mind and asked for the support of government officials, N.R.C., Marine Institute, etc. Since that time, I understand a proposal has been submitted for funding through N.R.C. At the moment, the project is somewhat on hold as they're looking at the feasibility of such an operation. The idea is to have a small experimental fish silage operation set up in the Leading Tickles area. They've also looked at the possibility of using waste fish material for making organic fertilizer, mixing it with peat, etc.

At the start of today's session, it was mentioned there are two processes for making silage; one involves adding acid and is an autolytic type process. The other one that was mentioned was the fermentation process and not much was said about it.

I remember a couple of years ago being at our old premises on the south side and being introduced to a gentleman by the name of Bill Moores. He was a Newfoundland inventor and had invented a peat-type material for absorbing oil spills. He had done some research into the fermentation processes that have been reported in the literature for converting silage and I guess he came up with his own process. I remember he did some of the initial demonstrations at our premises and I can remember him taking ground-up fish material and adding to it what looked to me like hay. What I would say was hay, was some secret

mixture. He mixed this in with the ground-fish material, put it in small plastic bags, put a twist-tie on it, and almost before your eyes the bags would start to fill up and the material would start working almost immediately. He tried to get the interest of one of the large fish processors in Newfoundland, Fishery Products International, and eventually down the road, with funds from N.R.C., they did some work at the fish plant in Harbour Breton. It was my understanding from talking with the gentleman in charge, working with the company, Hazel Industries, that samples had been produced and feeding trials were under way and this spring the results of such said trials were to be made known. But since that time, since I've come here, I've talked with the gentleman who presented the paper on feeding hogs and he tells me that no such trials have taken place. Before I came I checked again with N.R.C.

to see what was happening with regards to this venture and they tell me that they are in the process of patenting the process and raising capital and getting funding for a two-year project.

So that, essentially, is what's happening in Newfoundland in the area of fish silage.◊

OTHER ACTIVITIES TUNS

John H. Merritt
Canadian Institute of Fishing Technology
Technical University of Nova Scotia
Halifax
Nova Scotia
B3J 2X4

INTRODUCTION

It would appear, from the plans and proposals for farmed salmon in Atlantic Canada, since total production rates well in excess of 10,000 tonnes per year have been mentioned, that there is ample scope for the manufacture of fish silage as a fish feed. A demand for 20,000 tonnes per year for fish for silage production, which would be sufficient to produce roughly 4,000 tonnes of salmon per year, for example, could take up all or most of the surplus roe herring in southwest Nova Scotia and so alleviate the serious problem of disposal.

It may be of interest to set these rates against figures, in round numbers, for waste fish in Atlantic Canada. Fish meal and oil accounts for 260,000 tonnes per year. Other by-products account for little more but the total amount of waste fish will be substantially higher, perhaps more than 360,000 tonnes per year.

The Canadian Institute of Fisheries Technology (as has been mentioned by previous speakers) has carried out work concerned with fish silage, including tasting tests on pork for Agriculture Canada and, mostly for the Nova Scotia Department of Fisheries, production and processing of silage on a pilot scale.

Recent trials at the Institute have included some examination of water and oil separation from silage.

RECENT TRIALS

Trials have been carried out in the pilot plant to examine the production of silage from cod and herring in batches of 50 kg. Heating and adjustment of pH were examined as preliminary treatments, to enable separation of liquid and solid phases in a screw press.

Lipid contents of the raw fish, and the cake, liquid and

final silage product were determined. Fatty acid analysis was conducted on the lipids of the fish and final silage, with emphasis on the content of docosahexaenoic acid (22:6n3).

The lipid levels in the herring used ranged from 7-10% and lipid levels in the final silage were generally in the same range. The amount of 22:6n3 in the herring ranged from 6-9%. The amounts did not vary for silage at normal pH but showed a wide range where the pH was adjusted. Possibly adjustment allowed for an enrichment of 22:6n3 through loss of triglycerides and preferential retention of phospholipids, where the highly polyunsaturated acids are usually associated.

Generally separation of solid (other than bones) from the liquor was poor. The heated protein was, to a large extent, broken down and incorporated into an 'emulsion' with water and oil during the mixing/heating process, making separation difficult.

It was possible, by pressing fish (herring) that had been heated to 70°C for 2 hours, to produce a 'cake' with no free liquid. The presence of acid made the cake stable at room temperature. Such material might be suitable as a feed in pellet form.0

I.M.A AQUATIC FARMING LTD.

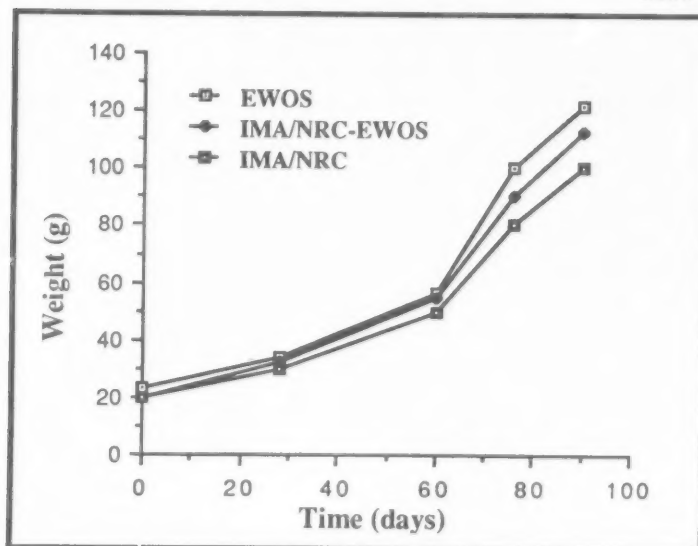
Brian Ives
I.M.A. Aquatic Farming Ltd.
Argyle Head
Nova Scotia
BOW 1W0

IMA Aquatic Farming Ltd. became interested in fish silage as a potential ingredient for fish diets in the summer of 1982. The Scandinavian studies on fish silage were carefully reviewed and the economic feasibility of the silage production unit was evaluated. A preliminary experiment was designed and silage was produced in cooperation with the National Research Council. The feeding trial was conducted to evaluate the performance of three diets: Commercial EWOS diet (dry), IMA/NRC silage diet (95% silage and 8% binder), and a combination EWOS and IMA/NRC silage diet. Results of this study are summarized in Figure 1. Rainbow trout of approximately 15g were fed these diets for 91 days. The growth of trout fed silage based diets was lower than commercial EWOS diet. However, the mixture of silage and dry diet showed better growth than silage alone. We also observed palatability problems, gut irritations and incidence of certain diseases. Some problems of vitamin deficiencies and nutrient losses in silage diets were also pointed out by

S. Lall. We were particularly concerned about nutritional diseases and subsequently terminated this work to revise and review our investigations.

We experienced some initial difficulties for support of the silage project. Last year, Department of Fisheries (Nova Scotia) accepted our proposal for the use of herring carcasses in the production of fish silage to be used in salmonid diets. They felt that large quantities of herring roe carcasses (24,500 tons) were buried at land or at sea. Some of these herring could be utilized for aquaculture feeds. It is likely that we will require 750-1500 tons of feed in our fish farming operation by 1990-91. If the feeding trials are successful, the major proportion of fish diet would contain fish silage (Table 1). We propose to incorporate higher proportions of fish silage in our salmonid diets than the existing Department of Fisheries and Oceans moist feed formulations.

Figure 1



A schematic proposal of our silage and feed processing plant is shown in Figure 2. Each silo holds 2500 kg of product. We have found that the quality of silage should be regularly monitored. Improper mixing of fish and acid causes a severe decrease in the quality of the product. We have now refined the mixer-grinder system and installed a special acid pump. We hope to add an additional mixer and grinding unit equipped with acid and mono pump units. Our cost estimates indicate that a fish farmer could set up such a unit for a cost of \$42,000 including the building. It is estimated that the cost of the finished silage would be approximately 4.5¢/lb. This is relatively cheap when compared with the cost of raw fish or other feed ingredients.◊

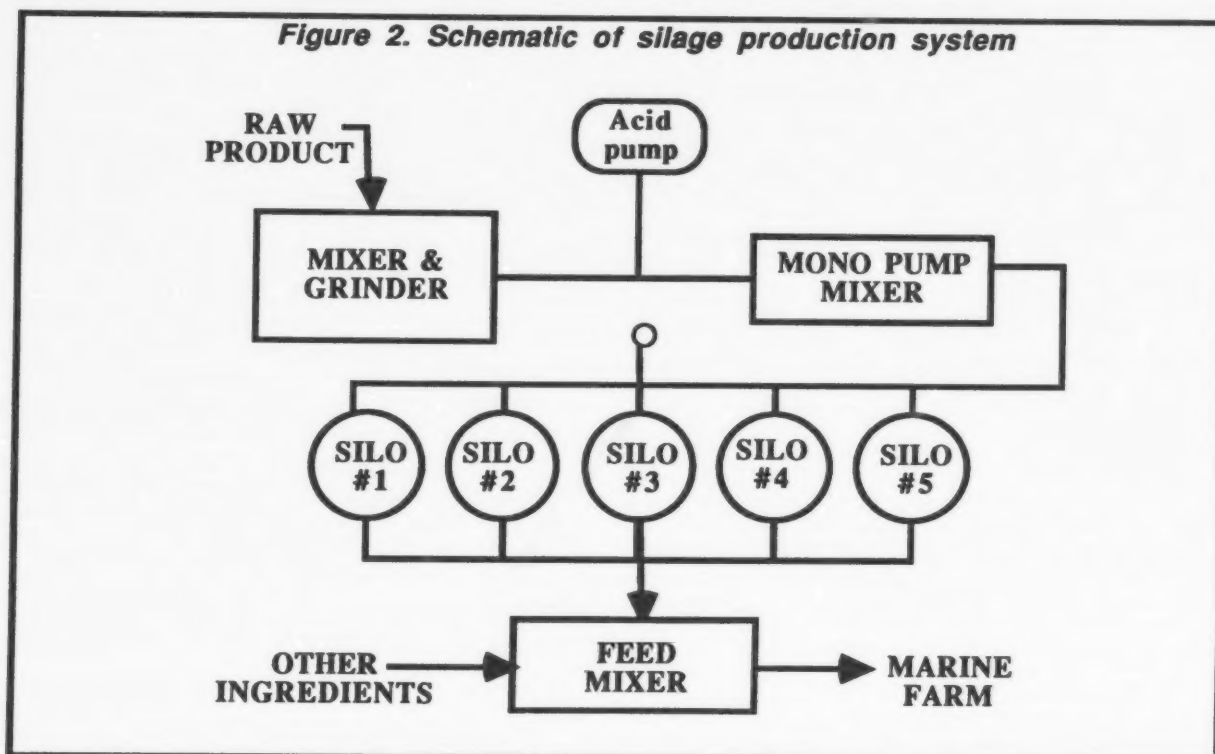
TABLE 1

PROPOSED RAINBOW TROUT DIET		Department of Fisheries and Oceans Atlantic Salmon Saltwater grower Feed formula (Moist) FORMULA: DF0H-85MG	
Ingredient	%	Ingredients	kg
Herring silage (oil present) ¹	57,0	Ground pasteurized fish	
Fish meal	25,0	(Gaspereau, herring and	
Herring oil	5,0	other scrap fish)	44,0
Wheat middlings & other binders	11,0	Fish meal, herring	
Choline Chloride (50%)	0,4	or capelin (65% crude protein)	27,0
Vitamin & Mineral Pre-mix	1,6	Soybean meal(48% C.P.)	8,0
		Wheat middlings (17% C.P.)	13,1
		Choline Chloride (50%)	0,4
		Vitamin premix (CF0H-85MG)	1,0
		Herring, capelin or salmon oil	6,0
		Mineral premix	0,5
		TOTAL	100kg

¹Free fatty acids less than 1,5%, ethoxyquin (50%), 450 ppm

Note: Formula developed and tested by Disease and Nutrition Section, Research Branch, Halifax, Nova Scotia. All ingredients must be ground finer than 0,25mm.

Figure 2. Schematic of silage production system



AGENDA

Tuesday, June 16, 1987

7:00 p.m.
7:30 - 9:30 p.m.

Registration
Reception and Mixer

Wednesday, June 17, 1987

8:00 a.m.	Registration
9:00 a.m.	Introductory Remarks by Jean-Eudes Haché
9:20 a.m.	Fish Silage: An Overview P.M. Jangaard Chief, Fisheries Development Branch Department of Fisheries and Oceans Halifax, Nova Scotia
10:00 a.m.	Coffee Break
10:15 a.m.	Silage Processing Plants: Ashore and Onboard Vessels N.I. Viken, Senta Ltd. Hamar, Norway Fish Silage Concentrate: Manufacture and Use O.P. Ulvestad Royal Seafood Ltd. Trondheim, Norway
11:45 a.m.	Discussion: Other processes, canadian sources.
12:20 p.m.	Lunch
1:30 p.m.	Silage as Feed for Salmon and Trout Dr. S. Lall, Science Branch Department of Fisheries and Oceans Halifax, Nova Scotia
2:15 p.m.	Silage as Animal Feed T. VanLunen, Canada Department of Agriculture Experimental Station Nappan, Nova Scotia

3:00 p.m.

Coffee Break

3:15 p.m.

**Experiences and Opportunities
in the Atlantic Provinces**

Activities by Province

George Richard/Mike Drebot
Department of Fisheries
Province of Nova Scotia

Dr. R. Cook,
Biological Station
St. Andrews
Province of New Brunswick

Dr. C. Frantsi
Connors Bros. Ltd.
Black's Harbour
Province of New Brunswick

John L'Aventure
Fundy Aquaculture Ltd.
Grand Manan, New Brunswick

Dominic Johnson
P.E.I. Department of Agriculture
Charlottetown
Province of Prince Edward Island

Ms. Andrée J. Gendron
Department of Agriculture, Fisheries and Food
Gaspé
Province of Quebec

Winston King
Marine Institute
St. John's
Province of Newfoundland

Other Activities

John Merritt
Canadian Institute of Fisheries
Technology, Technical University of N.S.
Halifax, N.S.

Brian Ives,
IMA Aquatics Ltd.
Glenwood, N.S.

4:15 p.m.

Discussion and Conclusion

5:00 p.m.

Adjournment

ATTENDEES

Cape Ann Seafoods Limited
Port Latour, N.S.
B0W 2T0

Allan Anderson
Aquaculture

Paul Arnold
National Sea Products Ltd.
P.O. Box 2130
Halifax, N.S.
B3J 3B7

Florian Bertrand
F. Bernard Inc.
2200 rue Pratte, Suite 276
Saint-Hyacinthe, Qc
J2S 4B6

Doug Bertram
Alan Fisheries Limited
P.O. Box 21
Digby, N.S.
B0V 1A0

Paul Blinn
Independent

Mark Blinn
Innovative Fishery Products
Mavillette, N.S.

Jean-Marie Boucher
Department of Agriculture, Fisheries and Food
1020 route de l'Église, 4e étage
Ste-Foy, P.Q.
G1R 4P3

Leonard Boudreau
P.O. Box 1085
Sydney, N.S.
B1P 6J7

André & Gérald Boudreau
Hog Farm
R.R. #1
Church Point, N.S.
B0W 1M0

André Boudreau
B.C.D. Fisheries Limited
R.R. #1
Church Point, N.S.
B0W 1M0

André Boudreau
Richmond Fisheries Inc.
P.O. Box 40
Petit-de-Grat, N.S.
B0E 2L0

Kevin Brown
Lunenburg Foundry & Engineering Ltd.
53 Falkland St.
Lunenburg, N.S.
B0J 2C0

Joe Casey
Casey Fisheries Limited
P.O. Box 86
Digby, N.S.
B0V 1A0

Roland Comeau
C & K Fisheries Ltd.
P.O. Box 127
Meteghan, N.S.
B0W 2J0

Hubert Comeau
AWH Enterprises Ltd.
R.R. #1, Box 144
Saulnierville, N.S.
B0W 2Z0

Paul Comeau, Warden
Municipality of Clare
Little Brook, N.S.
B0W 1L0

Louise Comeau
Lady Gaudet Fisheries
Box 176
Meteghan, N.S.
B0W 2J0

Delphis Comeau
Municipal Clerk
Municipality of Clare
Little Brook, N.S.
B0W 1L0

Gerald, J.B. Comeau
Cape Saint Mary Fisheries Limited
R.R. #1
Yarmouth, N.S.
B5A 4A5

Dr. R.H. Cook
Department of Fisheries and Oceans
Fisheries Research Branch
St. Andrews, N.B.
E0G 2X0

Cathy Crory
Ocean Products
P.O. Box 263
Eastport, Maine
04631 U.S.A.

Clayton d'Entremont
St. Mary's Bay Fisheries
Meteghan, N.S.
B0W 2J0

Noël Després
Comeau's Sea Foods Ltd.
P.O. Box 39
Saulnierville, N.S.
B0W 2Z0

Michael Deveau
Cape Saint Mary Fisheries Ltd.
R.R. #1, Yarmouth, N.S.
B5A 4A5

Michael Drebot
N.S. Department of Fisheries
P.O. Box 2223
Halifax, N.S.
B3J 3C4

Andrew Duthie
Department of Fisheries and Oceans
200 Kent St, #1132
Ottawa, Ont.
K1A 0E6

John Hue Edwards
Department of Rural Development
Grand Falls, Nfld.

Eric Efford
Van Waters & Rogers Ltd.
2 Fielding Ave., Suite A
Dartmouth, N.S.
B3B 1E

Jim Eisenhauer
Atlantic Bridge Co. Ltd
Lunenburg, N.S.
BOJ 2C0

M. Alphonse Gagnon
Department of Agriculture, Fisheries and Food
Service d'aide technologique aux entreprises
200-A, Chemin St-Foy
Québec, Qc
G1R 4X6

Andrée Gendron
Department of Agriculture, Fisheries and Food
96 Montée Sandy Beach, C.P. 1070
Gaspé, Qc
G0C 1R0

Jean-Eudes Haché
Director General
Department of Fisheries and Oceans
1640 Hollis Street
Halifax, N.S.
B3J 2S7

Ian K. Hamilton
Salmonid Seaculture Ltd.
R.R. #4, Lime Kiln Road
St. George, N.B.
E0G 2Y0

Bob Harding

Loretta Hastandrea
Sea Raven Resources Ltd.
P.O. Box 7091
Halifax, N.S.
B3K 5J5

M. Glenn Hayes, Agrologist
La Fédération de l'U.P.A. de la Gaspésie
C.P. 9
Cap Noir, Gaspé
G0C 1C0

Mad. Louise Hébert
N.B. ERDA Coordinator
Department of Fisheries and Oceans
Moncton, N.B.
E1C 9B6

Gene Henderson
Salmonic Seaculture Ltd.
R.R. #4, Lime Kiln Road
St. George, N.B.
E0G 2Y0

Ove Hjelkrem
Lawrence Sweeney Fisheries Ltd.
Yarmouth, N.S.
B5A 4B2

Brian Ives
IMA Aquatic Farming Ltd.
R.R. #1
Glenwood, N.S.
B0W 1W0

Gordon Johnson
Johnson Development Ltd.

Dominic Johnson
R.R. #1
Winsloe, P.E.I.
C0A 2H0

Peter Jangaard
Chief, Fisheries Development Branch
Department of Fisheries and Oceans
Halifax, N.S.
B3J 2S7

Karen Kennedy
Regional Chemist
Inspection Services Branch
P.O. Box 5667
St. John's, Nfld.
A1C 5X1

Frank King
Department of Fisheries and Oceans
1649 Hollis St.
Halifax, N.S.
B3J 2S7

Winston King
Marine Institute
P.O. Box 4920
St. John's NFLD
A1C 5R3

Daniel Lacombe
Department of Technology and Commerce
P.O. Box 6000
Fredericton, N.B.
E3B 5H1

Dr. Santosh Lall
Department of Fisheries and Oceans
1707 Lower Water Street
P.O. Box 550
Halifax, N.S.
B3J 2S7

Eric Lavoie

John Leary
ABCO Industries Ltd.
P.O. Box 1120
Lunenburg, N.S.
B0J 2C0

Alphée LeBlanc
Cape Saint Mary Fisheries Limited
R.R. #1
Yarmouth, N.S.
B5A 4A5

Hubert LeBlanc
Spectacle Lake Farm
R.R.# 1
Church Point, N.S.
BOW 1M0

Dave Lemon
Department of Fisheries and Oceans
P.O. Box 550
Halifax, N.S.
B3J 2S7

Don MacNeil
Department of Regional Industrial Expansion
P.O. Box 940
Station M
Halifax, N.S.
B3J 2V9

Richard A. Malone
Fish Reduction Ltd.
Goose Lake
Shelburne Co., N.S.
B0T 1W0

Dr. John Maloney
Fisheries Resource Development Ltd.
2021 Brunswick St., #317
Halifax, N.S.
B3K 2Y5

Jim McAfee
Hudson's Bay

James McClare
James H. McClare Associates Ltd
P.O. Box 244
Elmsdale, N.S.
B0N 1M0

Richard McDormand
P.O. Box 56
Granville Ferry
Annapolis Co., N.S.

Peter McKelvey
Research and Productivity Council
P.O. Box 6000
Fredericton, N.B.
E3B 5H1

Frank McKinney
Department of Fisheries and Ocean
Gulf Fisheries Center
P.O. Box 5030
Moncton, N.B.
E1C 9B6

John Merritt
Canadian Institute of Fisheries Technology
P.O. Box 1000
Halifax, N.S.
B3J 2X4

Stephen Moffett
Penobsquis, N.B.
G0E 1L0

Sylvestre Muise
Université Ste-Anne
Church Point, N.S.
B0W 1M0

Dave Mullaby
Souris, P.E.I.
C0A 2B0

Marie-Hélène Munsch
Centre de recherche sur les aliments à Moncton
Université de Moncton
Moncton, N.B.
E1A 3E9

Mr. Lloyd Murphy
P.E.I. Department of Fisheries
P.O. Box 2000
Charlottetown, P.E.I.
C1A 7N8

Ray Nadding
National Sea Products Ltd.
P.O. Box 2130
Halifax, N.S.
B3J 3B7

Dave Oulton
Char-Vale Charolais Ltd.
Box 2232
Windsor, N.S.
B0N 2T0

Peter Partington
Area Manager, Southwestern Nova Scotia
Department of Fisheries and Oceans
215 Main Street
Yarmouth, N.S.
B5A 1C6

Mr. Luc Picard
Baie Chaleur Aquaculture
1450, boul. Perron Est, C.P. 10
Carleton, Qc
G0C 1J0

Ross Piercey
Manager, Seafood Surveys
SGS Supervision Services Inc.
10 Akerley Blvd., Suite 51
Dartmouth, N.S.
B3B 1J4

Gerard Pool
R.R. #1
Winslow, P.E.I.
C0A 2H0

Mrs. Elaine Price
RAND
Provincial Building
Grand Falls, Nfld.
A2A 1W9

Carl Reynolds
Department of Fisheries and Oceans
P.O. Box 1236
Charlottetown, P.E.I.
C1A 7M8

George Richard
N.S. Department of Fisheries
P.O. Box 2223
Halifax, N.S.
B3J 3C4

Danielle Rivard
Centre québécois de la Valorisation de la Biomasse
Faculté de l'Agriculture
Université Laval
Québec, P.Q.

Dominique Rony
Research Station Deschambault
Port Neuf, P.Q.
G0A 1S0

Jim Sandall
Nova Scotia Department of Fisheries
Founders Square Building
1701 Hollis St., P.O. Box 1087
Halifax, N.S.
B3J 2X1

Christopher Saulnier
Aqua Fish Farms Ltd.

Brian Saulnier
Sea Crest Fisheries Ltd.
P.O. Box 99
Saulnierville, N.S.
B0W 2Z0

Eric Smith
Box 28, Site 5
R.R. #3
Moncton, N.B.
E1C 8J7

Ted Sollows
Department of Fisheries and Oceans
215 Main St
Yarmouth, N.S.
B5A 1C6

J. Spinney
Atlantic Quality Concepts
P.O. Box 257
Shediac Bridge, N.B.
E0A 3H0

Dick Stewart
Atlantic Herring Fishermen's Marketing Coop Ltd.
P.O. Box 517
Yarmouth, N.S.
B5A 4BA

Andrew Strak
Fisheries Resource Development Ltd.
2021 Brunswick St, #317
Halifax, N.S.
B3K 2Y5

Donald Stucklass
Exploits Valley Development Association
P.O. Box 246
Grand Falls, NFLD

Michael Theriault
N.B. Department of Fisheries
P.O. Box 6000
Fredericton, N.B.
E3B 5N1

Gérald Thimot
G.E. Thimot Excavations Ltd.
Saulnierville, N.S.
B0W 2Z0

Ole Peter Ulvestad
Royal Seafood Ltd.
Olav Tryggvasonsgt 40
N - 7000 Trondheim
Norway

Ted VanLunen
Agriculture Canada Research Station
Nappan, N.S.
B0L 1C0

Wayne VanToever
Integrated Aquatic Systems
R.R. #2
North Wiltshire, P.E.I.
C0A 1Y0

Nils Ivar Viken
Senta Ltd.
P.O. Box 133
2301 Hamar
Norway

Clément Villeneuve
Pêches et Océans Canada
901 Cap Dumont
Québec, Qc
G1K 7Y7

Eric Way
Department of Fisheries and Oceans
P.O. Box 5667
St. John's, Nfld
A1C 5X1

Ian Weus
16 Crescent Ave.
Moncton, N.B.
E1A 3J3

Jimmy White
J.W. Fisheries
Box 3010, R.R. #1
Yarmouth, N.S.
B5A 4A5

Pete Winchester
Fisheries and Oceans
Yarmouth, N.S.
B5A 1C6

Mr. Andy Woyewoda
Technical University of Nova Scotia
P.O. Box 1000
Halifax, N.S.
B3J 2X4

Byron Wright
Preferred Holding Ltd.
Vancouver, B.C.